CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK No. 14

1915

PUBLISHED BY THE INSTITUTION
WASHINGTON, U. S. A.

WASHINGTON, D. C.
PRESS OF GIBSON BROTHERS.

OFFICERS FOR THE YEAR 1916.

LIST OF PRESENT AND FORMER TRUSTEES.

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904:

The President of the United States.
The President of the Senate.
The Speaker of the House of Representatives.
The Secretary of the Smithsonian Institution.
The President of the National Academy of Sciences.

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ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington.* (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort.. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

FOURTEENTH MEETING OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF THE FOURTEENTH MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington, in the Board Room of the Administration Building, on Friday, December 10, 1915, and was called to order at 10 o'clock a. m. by the chairman, Mr. Root.

Upon roll-call by the secretary, the following Trustees responded: Cleveland H. Dodge, Charles P. Fenner, Henry L. Higginson, Charles L. Hutchinson, Henry Cabot Lodge, Andrew J. Montague, William W. Morrow, Wm. Barclay Parsons, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Theobald Smith, Charles D. Walcott, Henry P. Walcott, Andrew D. White, Henry White, George W. Wickersham, Robert S. Woodward.

The minutes of the thirteenth meeting were approved as printed and submitted to members of the Board of Trustees.

The reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of directors of departments and grantees of the Institution were presented and considered.

The following appropriations for the year 1916 were authorized:

Administration	$50,000.00
Publication	60,000 00
Division of Publications	10,500.00
Departments of Research	644,236.00
Minor Grants	104,832 18
Index Medicus	12,000.00
Insurance Fund	25,000.00
Reserve Fund	250,000.00
	$1,156,568 18

The resignation of Mr. William H. Taft was presented and accepted with regret.

Vacancies in the Board were reported, caused by the death of Mr. William N. Frew and by the resignation of Mr. Taft. Balloting to fill the vacancies resulted in the election of the following persons to membership in the Board:

Mr. Myron T. Herrick, of Ohio.
Dr. Stewart Paton, of New Jersey.

The officers of the Board were reelected for the ensuing three years as follows: Mr. Root, chairman; Mr. C. D. Walcott, vice-chairman; Mr. Dodge, secretary.

Messrs. Parsons, Pritchett, and Welch were elected as members of the Executive Committee to succeed themselves for a term of three years; Messrs. Dodge (chairman), Pritchett, and Wickersham were reelected as a Finance Committee for a term of three years; and Messrs. Brookings (chairman), Hutchinson, and Wickersham were reelected as an Auditing Committee for the same period.

The Board adjourned at 1 p. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1915.

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1915, along with recommendations of appropriations for the ensuing year and with sundry suggestions concerning other matters of general or special interest.

This report is the fourteenth annual report of the Institution and is presented under the following principal heads:

1. Salient events of the year.
2. Characteristics of the Institution.
3. Financial records.
4. Publications.

SALIENT EVENTS OF THE YEAR.

In the first month of the fiscal year to which this report applies the Institution lost by death two distinguished Research Associates, namely, Alfred Thayer Mahan, Rear Admiral, U. S. N. (retired), and Charles Sedgwick Minot, professor of comparative anatomy in the Medical School of Harvard University. By reason of his penetrating insight as a student of history, and especially by reason of his unrivaled interpretation of military and naval affairs, Admiral Mahan had been invited to devote part of the year as an adviser to the Department of Historical Research. He had just undertaken this office with characteristic zeal and discernment when he succumbed to an attack of pneumonia. His interest in national and international development and his keen perception of causes and consequences in the world of politics made him an uncommonly effective counsellor in all matters historical. To this competency there was added a rare combination of philosophic clarity and modest candor which fitted him better

Deaths of Research Associates.

perhaps for the reflective work of research than for the executive work of his chosen profession.

Professor Minot was one of the best known and highly esteemed of American men of science. While his range of studies included the entire group of subjects now implied by the term biology, he was an authority especially in anatomy and embryology. He was deeply interested also in other branches of science and likewise in the progress of science as a whole. He took an active part in the organization of the numerous special societies which have sprung into existence in recent decades out of the American Association for the Advancement of Science; and at the same time he was equally effective in the constructive work essential to conserve the continuity and the prosperity of the parent organization. In addition to this conspicuous service to American science, he was long an influential trustee of the Marine Biological Laboratory at Woods Hole, Massachusetts, while his administration of the Elizabeth Thompson research fund was a model at once of fidelity and efficiency.

Effects of European War.

With the progress of the European war the wisdom of a general suspension of the Institution's activities in the belligerent countries became increasingly evident. Accordingly, all Research Associates who are citizens of the United States have been withdrawn from the war zones and nearly all work of the Institution hitherto under way, or planned for, in belligerent territory has been suspended. This has required many changes of plans, particularly in the Departments of Historical Research and Terrestrial Magnetism, and it must delay the researches of a number of investigators who are now excluded in part from access to the sources of information essential to their several fields of inquiry. Except for these restrictions the direct effects of the European war on the work of the Institution have not been serious, and the inevitable indirect effects, which may be much more detrimental, have not had time to manifest themselves. How these indirect effects, now slowly evolving, may fall upon research and allied organizations can not be clearly foreseen; but the unparalleled destruction of life and of property now going on in Europe may be confidently expected to entail closely related though probably quite

different and less disastrous results in neutral countries. A fact of great importance to any adequate interpretation of the evolution of civilization, illustrated by the history of nearly every nation, is that the general advance in knowledge and in social melioration of our race is not inconsistent with occasional, and at times considerable, steps backwards. In the light of this fact it is not inconceivable that the principles and the methods fundamental and indispensable to research organizations may undergo temporary eclipse as a result of the pending conflict, as they have often undergone eclipse in the past. It is a duty, therefore, to be aware of the possibility of such a calamity, although the probability of its occurrence is happily small.

Panama-Pacific Exposition.

An interesting and instructive event of the year is the participation of the Institution in the Panama-Pacific International Exposition, for the reason that preparation therefor required a narrowly limited choice of illustrations of methods and results of research designed to appeal to a wide range of popular interests, and for the reason that an unusual opportunity was thus afforded for getting an objective estimate of the Institution's functions in contemporary society. An attempt was made to convey information quickly to the average visitor by means of photographs and models; by free distribution of a special edition of the pamphlet explaining the plan, scope, and development of the Institution; by similar distribution of a classified list of the publications of the Institution, and by exhibition of a uniformly bound set of these publications themselves.

That estimates of a research organization made by miscellaneous observers of such an exhibit must vary widely should go without saying, since there is still more or less of conflict of opinion among experts as to what research is and how it may be advantageously pursued. It is in evidence, indeed, that while certain principles fundamental to investigation and to extension of learning thereby are, like Newton's laws of motion, well established, they are by no means commonly understood and appreciated. Progress is, in general, slowly achieved and more slowly assimilated. The philosophy and the science of our ancestors, long antecedent to the present epoch, are still domi-

nant over the majority of mankind. It was to be expected, therefore, that the estimates in question would be somewhat clouded by inappropriate ancestral prepossessions and by modern popular tendencies, especially of the public press, to exaggerate and to attribute to occultism the plainest products of forethought, industry, and application of well-known principles. It has been gratifying to observe, however, that in this novel experience with the Panama-Pacific Exposition, as in other experiences alluded to in previous reports, there is manifest an active leaven of intelligent desire to discover what are the essentials of a corporation designed to promote altruistic investigation, to differentiate these essentials from what is adventitious to them, and to measure the Institution's right to existence by the more stable standards of capacity to contribute permanent additions to the sum of verifiable and hence available knowledge.

Popular Recognition of Scientific Method.

But there are more important indications of an increasingly favorable attitude of the public towards research than those just referred to. That the scientific method, which furnishes the instruments and the criteria for effective investigation, is now gaining esteem with unreflective as well as with reflective minds is in evidence in nearly every field of current activity. In the report for the year 1914 attention was called to the rise of other research establishments and to the relations of reciprocity the Institution should sustain to them. Several of these have effected organization during the past year and more such are in process of development. They are destined to aid greatly in rationalizing popular concepts of the meaning and objects of research and particularly of the costs involved and the greater economies to be gained thereby. Concerning these latter rather simple arithmetical matters the wildest illusions are prevalent; they are formidable obstacles to progress and nothing short of a more general distribution of responsibility appears adequate to dislodge them. Nearly all of the difficulties and dangers encountered by the Institution may be attributed to the persistency of these ubiquitous illusions, which would be more fitly characterized as delusions if they were not so common. The obvious fallacies entertained, and the fatuous misrepresentations disseminated, with respect to the Institu-

tion's income a decade ago have entailed on our contemporaries and successors a burden of harm which will require another decade, or perhaps a generation, to remove; and in the meantime, recrudescence of such popular aberrations will constitute a menace to the perpetuity of any organization whose endowment is continually confounded with its income.

Simultaneously also with the rise of other research organizations, the scientific method is rapidly gaining control in the direction of commercial and industrial enterprises. Indeed, the phrases "scientific management," "industrial efficiency," and the like, are now so much overapplied and so often misapplied as to render them offensive to judicially conservative minds; for herein likewise, as in most other contemporary affairs, there is a popular tendency to anticipate the marvelous and hence to obscure the realities of the forward movement now going on. Thus one might infer from current literature that the doctrine of efficiency is altogether new and that it has sprung suddenly from a few Americans and from the general staff of the German army. It is unnecessary here to explain that this doctrine is not new, that it has undergone a long course of development, and that it did not originate as commonly supposed. What is new about it is a growing collective consciousness of its validity and a rapidly increasing apprehension of the advantages it may bring in many, if not most, fields of endeavor. But appreciation of this doctrine is neither more nor less than a recognition of the scientific method whose beginning dates far back, prior to the period of unwritten history of primitive man.

A far-reaching effect of the determinate introduction of the principles of science in commercial and industrial affairs is seen in the resulting diffusion of sound learning among the masses of men. Increase in efficiency in such affairs requires, in general, application of a wide range of demonstrable principles, all of which must stand the tests of economic practicability. The so-called laboring man, therefore, as well as the manager, must become familiar with a correspondingly wide range of facts, methods, and appliances affording typical illustrations of those principles. Thus many manufacturing plants are now great laboratories supplying instruction to operatives, although nominally conducted with quite other objects in view; while some

individual machines, like the internal-combustion engine, embody in their construction and operation striking and easily acquired lessons in certain fundamentals of physical science. But what is more important in this connection is the general recognition of research as an essential preliminary to progress. Accordingly, numerous national organizations are now forming research committees for the investigation of problems common to their several interests, while not a few individual establishments are conducting special research laboratories whose contributions to knowledge must be justly measured by a much higher standard than that of commercial profit alone. In this process of evolution the conventional divisions of pure and applied science are coming into closer contact and the invidious distinctions between them, often set up disadvantageously to both, seem to be slowly disappearing.

Costs of Research.

Fundamentally related to the application of the scientific method in increasing measure in nearly all fields of inquiry is the question already alluded to of the costs involved, although it has been little considered and is often contemptuously disregarded both by enthusiastic investigators and by optimistic financiers. It is, in fact, in its entirety, often a question of great complexity, involving as a rule many difficulties with "personal equations" and all of the entanglements due to the uncertainties which successful research seeks to remove. It is too large a question for adequate discussion here, but a statement of certain of its more obvious aspects may help to remove common misapprehension with respect to the Institution and thus aid other similar organizations to develop in a rational manner. Briefly, these aspects may be stated as follows; they are so self-evident that formal expression of them would be superfluous if they were not contradicted in daily experience:

1. Sound research, like any trustworthy work, is expensive in proportion to its comprehensiveness and thoroughness.

2. The number of projects worthy of investigation is now far greater than can be adequately financed, and hence advantageously pursued, either by any single agency or by all such combined; and the prevalent lack of financial support for this kind of work appears destined to continue indefinitely, certainly so

long as there is no general recognition of existing conditions or of practicable ways of improving them.

3. Each research organization must therefore choose for itself at any epoch the field, or the fields, it will cultivate, and must restrict itself to them. No such privately endowed organization may seek to delegate its duties to others, to play the rôle of paternalism, to undertake the functions of a scientific clearing-house, to secure monopolistic privileges, or to engage in propagandism, without danger of defeating its primary purposes.

That large sums are now spent annually by governments, by municipalities, and by industrial organizations in defraying the costs of investigations, sums vastly greater in the aggregate than the combined incomes of all existing endowed research organizations, is a fact which needs to be visualized as a preliminary to an understanding of the relatively narrow limitations of the resources and capacities of the Institution. Thus, to illustrate, in the conduct of work which may be fittingly called research, the United States Government spends annually not less than twenty times the income of the Institution. It matters not that this work is often designated by the ambiguous word "practical," or by the misleading phrase "applied science." In so far as it deals with facts and principles, and substitutes knowledge for ignorance, it is worthy of prompt recognition and unstinted support. If, for example, the United States Department of Agriculture can succeed in supplanting "lunar methods" in husbandry by methods founded on physical fact and verifiable induction, it will be entitled to conspicuous distinction in the annals of American science. But while antithetical words and phrases continue to befog contemporary thought it may be easily ascertained, and should be better known, that the United States Government, through its numerous departments and bureaus, is now carrying on, and has in recent decades accomplished, a large amount of high-class research, the annual costs of which quite overshadow the income from any existing research endowment. It may be as easily ascertained, and should be as well known, that no such endowment can be reasonably expected to supplant governmental functions or to supplement governmental resources. The legislator who sees no reason why the Institution may not undertake electrification of postal routes, the pub-

licist who entertains fear lest a few endowed organizations should secure a monopoly of research, and the educator who imagines the income of the Institution sufficient to meet academic needs and emergencies, are all alike deceived by fallacies which become manifest as soon as one is asked to assume responsibility for their consequences.

Financial Status of Institution.

In connection with these matters of public concern, it is fitting to remark that while the world at large has entertained all manner of fictitious expectations from the Institution, its actual development has proceeded in conformity with the limitations of its income and the conditions of its environment. Quite contrary to popular impressions, these limitations and conditions have been carefully observed; and the facts and figures relative to annual and to aggregate expenditures have been set forth in every annual report and may be found brought down to date in the financial section of this report. There is no adequate reason, therefore, why any one desiring to know these facts and figures may not get them along with certifications of their correctness by public auditors. Although doomed to fall far short of the totality of the expectations referred to, the Institution has expanded very rapidly and is now engaged in so many fruitful enterprises that others may not be undertaken in the near future without a considerable addition to annual income. As a matter of fact, it is now essential to curtail research in order to live within income, since the purchasing capacity of monetary standards, which has fallen by more than 30 per cent during the last two decades, appears to be still diminishing.

CHARACTERISTICS OF THE INSTITUTION.

Theory of Research.

Aside from the high purposes set forth by the Founder in his Deed of Trust and the declaration of maxims for general guidance made by the Executive Committee in the first Year Book, there has appeared no public statement of the theories of procedure in the Institution, or of the objects to be attained. These prime characteristics have, indeed, developed in large degree along with the Institution's growth. It has furnished an extensive and probably unequaled experience, chiefly destructive to inappropriate theories and to impracticable objects. For this reason, mainly, it has not seemed opportune hitherto to make any additional formal statement concerning these matters, although many inferences from the ruthless experience just referred to have been indicated here and there in the ten preceding reports. It appears advantageous now, however, in the interests of all concerned, after a decade of patient observation of actual developments and of considerate attention to an unsurpassed wealth of private and public opinion, to state briefly the ideas and the ideals which have animated the present administration and which seem fitted to endure in the conduct of any similar organization. Certain special reasons why altruistic establishments should reexamine, revise, and restate their articles of faith from time to time are found in the well-known persistence of influences inimical to progress and in the well-known tendency of such establishments, like biotypes, to revert to antecedent forms. Thus, for example, it is now happening that many of the fallacies which have beset the development of the Institution are recurring in the experience of the more recently founded research organizations. Moreover, there is always danger of such unfavorable reversion in any establishment whose governing body, or legislative assembly, is subject to rapid changes by reason of death or political revulsion. Experience of the past is easily forgotten, and there are few lessons so little utilized as those of human history.

Definitions are here essential and of these the first needed is one of the Institution itself. In its earlier years President Gilman found it easier to explain what the Institution is not than to define what it is. Elaborating his negative characterization,

one may say that the Institution is neither a college, nor a university, nor a museum, nor a library, nor an intelligence office. Neither is it a disbursing agency awaiting suggestions for applications of its income; nor is it a bureau for the perfection and promotion of inventions or for the exploitation of monopolies of any sort. The Institution is rather an establishment for the conduct and for the promotion of original research, the results of which are given freely to the world without restrictions implied by letters-patent and without privileges derived from copyrights. But while this positive definition, adopted essentially at the foundation of the Institution, has been thus far closely adhered to, the necessity for the negative definitions cited has not sensibly diminished. Indeed, there is a constantly recurring proclivity to reverse the signs of these definitions and hence to prolong indefinitely the more voluminous but generally fruitless parts of the Institution's correspondence. This latter continues to furnish daily an overabundance, especially, of evidence that the distinctions between invention and investigation and between education and research are rarely perceived and more rarely applied.

So many of the multifarious implications of these distinctions, which serve to differentiate the Institution from other organizations, have been considered in previous reports that mere allusion to them may suffice here. It is more important in this connection to offer an answer to the underlying question perennially put directly and indirectly to the Institution, namely, "What is research?" The answer to this question is contained in the answer to the larger question, "What is science?"; for, as indicated in an earlier section of this report, the methods of research are the methods of science. The meaning of this much used and much misused term is now well defined. It was established during the last half of the nineteenth century, although in common parlance it may still mean anything from "skill in boxing" to the prediction of solar and lunar eclipses. In a summary way science presents itself under three distinct stages, to wit: (1) the elementary stage of observation and experiment, or the fact-gathering stage; (2) the secondary stage of comparison, measurement, and calculation, or the statistical stage; (3) the stage of correlation under theory with capacity for prediction. But within the limits of

these distinct stages there is endless diversity of detail and hence the widest latitude for amateurism, dilettantism, and even pseudo-science. Thus it happens not infrequently that inquiry is made whether the Institution undertakes any other than "scientific investigations," whether its work is limited to science, or whether it seeks to enter the domains of philosophy, metaphysics, etc. Concerning these matters it may be said that the attitude of the Institution is at once liberal and critical, liberal in recognizing all branches of demonstrable knowledge and critical in respect to all unverified and unverifiable representations. No attempt has been made to limit recognition to the domain of mathematico-physical science or to the quite unhappily designated domain of "natural science." It should be said, however, that complete equality in application of the Institution's income has not only not been attained, but that such equality is in the nature of things unattainable.

It would be rash to assert that the methods and the inductions of science, which have cost more than twenty centuries of laborious effort in their evolution, are not still susceptible of many or even endless improvements. But these methods are now so well defined and so well known by all acquainted with the history of human progress that it is no longer essential to use the adjective "scientific" in qualification of the words investigation and research. One may safely assume, for administrative purposes at any rate, that investigations which purport to be unscientific or superscientific do not fall within the scope of a research organization. And in conformity with this view the term science may be no longer limited advantageously to designation of the mathematico-physical sciences (including the biological and the so-called natural sciences), which for certain obvious reasons have thus far helped most to fix its meaning. But while the term science should be interpreted in the most comprehensive and liberal manner, experience teaches that its criteria should be strictly observed and impartially applied. Liberality of inclusion and consideration may not be construed as implying leniency of judgment in matters scientific. Science furnishes no royal road to learning. It will undertake to blaze trails, to set up constructions conformable to the laws of the universe, and to test ideas, hypotheses, and theories; but it is unable to work in regions from which its methods and criteria are excluded.

Departments of Research.

The most striking characteristic of the Institution is found in its departments of research. These are absorbing the bulk of the Institution's income. They are devoted to fields of inquiry in which continuity of effort over long periods of time is a prime requisite. Their problems, like many of the phenomena under investigation, are of a secular nature and their progress may not be measured adequately in terms of an interval shorter than a decade. They are centers of activity which, if properly sustained, should continue to contribute additions to knowledge whose fuller fruition can be appreciated only by our successors.

In preceding reports brief summaries have been presented of the annual proceedings of these departments, but it appears more appropriate on this occasion to devote the space here available to some general observations in respect to departmental aims, needs, and attainable ideals. Herein, as in the preceding paragraphs, it seems worth while to register the impressions formed by a decade of experience with the affairs of these departments. They are extensive, highly technical, and in many respects highly complex establishments. They should be permitted, therefore, to report progress in their own ways and be required to assume due responsibilities therefor.

The questions most frequently raised with respect to these departments are (1) "What practical results are expected from them?"; (2) "Assuming them attainable, will the expected results justify the costs entailed?"; (3) "When will the work of any department be completed?"

(1) An essential preliminary in answering the first question is removal of the obscurity which commonly attaches to the word "practical." Those who use this word freely are rarely competent judges of research or of the accessions to learning secured thereby. What is practical to them is usually confined within the limits of personal experience instead of being permitted to fall within the far wider limits of the experience of our race. He who would venture an off-hand opinion concerning the practical, or directly realizable utilitarian, value of any proposed investigation must needs be uncommonly wise or possess a temerity not derived from an acquaintance with the history of science. This history demonstrates in the clearest manner that

every established fact, every newly discovered principle, and every generalization from fact and principle is sooner or later turned to advantageous account. Moreover, this induction from history is now so well established that a research organization as such should never concern itself seriously with the question whether a proposed investigation will turn out to be of immediate utility. The question it should ask is "Whether it is now practicable to undertake the proposed work and do it thoroughly well?" If this is decided in the affirmative, the organization may proceed with equanimity, confident of the final, even if doubtful of the contemporary, verdict. On the other hand, while holding to the views just indicated it is not necessary to ignore equally important items of mundane wisdom. It needs to be kept in mind that not all worthy subjects of research are at any epoch coordinately practicable of pursuit. In fact, as pointed out repeatedly in previous reports, there may be enterprises quite unready for investigation by a given organization at a given time, and other enterprises which under existing conditions would result only in a waste of energy and resources.

(2) In answer to the second question it may be said that while there is inherently an element of uncertainty in respect to the comparability of returns with outlay in the conduct of research, this uncertainty is in general much less than in most unexplored fields for investment of effort and capital. Systematic research is quite certain to secure some advances; even negative results are often of great value; and the elimination of error is almost as important as the discovery of truth. Here, again, appreciation of the time element is essential. A just verdict can not be rendered by our contemporaries; it must be left to posterity. Progress is not so much for the individual as for the race. It should be observed, also, that the costs of progress attributable to deliberate investigation have been, and are still, vanishingly small in comparison with the costs of the less contemplative forms of human endeavor. But who shall say that the permanent returns from these two contrasted realms of social effort are not more nearly inversely than directly proportional to the respective outlays? The appalling events now absorbing *the world's attention are painfully instructive in seeming to* prove that in some of his efforts to understand the cosmos wherein

he appears to play a unique rôle man has met with little or no success during the past twenty centuries; on the other hand, during the same interval, his efforts along scientific lines to interpret that cosmos have been rewarded by extraordinary advances, whose aggregate constitutes the bulk of the learning we may pass on unreservedly to our successors. The superiority of the learning of to-day over that of the first centuries of our era is indicated, for example, in the difference between the navigation of the Greeks and Romans by aid of knowledge and appliances available to them and modern navigation by aid of the compass, the sextant, and the nautical almanac.

(3) When the Institution was organized there was a widely spread opinion that much of its work would prove to be transitory, requiring here and there temporary subsidies to complete investigations already started and to publish conclusions already formulated. It was also commonly held that the Institution could act as a sort of promoter, starting by aid of initial grants many worthy undertakings and leaving them for subsequent support to the grantees themselves or to the establishments with which the grantees were connected. Closely related to these opinions was another to the effect that a large amount of valuable work could be accomplished under academic guidance by needy students who might thus earn from the Institution small stipends while doing the drudgery and acquiring the inspiration of research. But these plausible theories, praiseworthy enough in the abstract, failed to meet the requirements of conditions as they actually developed. It soon appeared that the completed investigations, or those nearly ready for publication, were not numerous. It was found that stimulating promising enterprises in other establishments by means of initial grants called, in general, for sustaining subsidies; and that in some instances such subsidies from the Institution had the sinister effect of decreasing independent support for research. And as for the students from whom so much for so little was expected, it turned out that they were preoccupied as a rule with the elementary notion that research means that modicum of investigation which leads to higher academic degrees.

Thus the Institution was compelled to recognize, in the face of much popular protest, what is clearly evident on reflection,

both from a priori argument and from common experience, namely, that productive research, like any other constructive work, requires arduous, persistent, and above all sustained effort under the direction of disciplined experts. Coruscations in science occur frequently enough, but unfortunately most of them, as every investigator knows, are ignes fatui. It is more rational, therefore, in the interests of progress to provide for continuity in research than to give special attention to the excessively rare events of sudden discoveries and inventions which prove to be of permanent value. These advances per saltum will take care of themselves; but the surer and more rapid process of general advance, and the one on which attention should be concentrated, in order to build for the future as well as for the present, is the process of summation of increments of knowledge, each relatively infinitesimal in comparison with the possible aggregate.

These considerations apply in greater or less degree to all branches of the Institution's work, but their application is indispensable to the highest success of the departments of research. Without continuity and without sustained activity and support they afford no adequate reasons for existence. It must be appropriately assumed, therefore, that their work will go on indefinitely, in the same sense, and for much the same reasons, that educational work is assumed to be endless. The incidence of their activities may be expected to change from time to time; their leaders and collaborators will come and go; but there is no prospect that their fields of investigation will become sterile or exhausted. Science is unable to assign an epoch for the beginning of research and may not venture to predict an end thereof; it may assert confidently only that its methods, which have proved effective and trustworthy in the past, will prove still more effective and trustworthy in time to come.

Division of Research Associates.

What has been said with respect to the departments of research applies with but slight modification to the activities of Research Associates. Their work includes in its aggregate a wider range of subjects and permits a larger degree of administrative freedom, but recognition of the time element is no less essential to this work than to that of the departments. Their progress must also be measured by

decades. Almost all of the investigations of Research Associates call, likewise, for sustained support. The popular theory of the efficacy of initial impulses and spectacular discontinuity has failed here as well as elsewhere in the inexorable experience of the Institution.

But when a reckoning by decades is conceded, when the proverbial difficulties of first steps are taken into account, and when an inventory of work already accomplished is contemplated, there appear to be no important reasons for regret in respect to this division of the Institution's work. Indeed, regret may be entertained rather that it is now impracticable, by reason of insufficient income, for the Institution to enlarge this division. It would be especially advantageous, if it were possible, to add a considerable number of associates who might be expected to devote their entire time to research. There is needed in the Institution, in order to secure a more favorable balance between observational and experimental science on the one hand and theoretical science on the other, a number of theorists in the better sense of the word. Quite naturally, if not inevitably, a large preponderance of the work of the Institution is on the observational-experimental side. Some steps have been taken already to correct this preponderance, particularly by the temporary assignment of Research Associates, eminent in their respective lines, to the departments of research; but these steps, while productive of highly satisfactory results, generally fall short of attainable ideals.

In connection with the present and with the preceding section of this report, it is fitting to remark that the productive capacity of the Institution could be greatly increased by a corresponding addition to its endowment without involving any important increase in the costs of administration. The preliminary experiments and investigations requisite to the development of stability in a novel organization have been made; and it is now time for the Trustees and the friends of the Institution to consider how its activities may be not only maintained but gradually extended along lines of carefully determined practicability.

A third principal characteristic of the Institution is found in its work of publication. Originally all phases of such work were merged in the general business of administration; but with the growth in magnitude and in complexity of all branches of this business it became desirable to separate the functions of book-making from those of book-distribution and other less technical duties of the administrative office. Accordingly, a Division of Publications devoted exclusively to the important requirements of editorial and press supervision was formally established in 1909. Simultaneously, this differentiation was emphasized by formal establishment of a Division of Administration, although it should be said that both of them had been recognized virtually some years before.

Division of Publications.

The Division of Publications, like the departments of research, has grown to be a highly technical and complex establishment, with a considerable and always expanding series of problems peculiar to its work. It has to deal with a great variety of subjects and a greater variety of authors. Problems of economy in illustration, in paper, in presswork, and in photographic reproduction, as well as of matters requisite to an exacting standard of quality, are constantly before it. What degree of success in the solution of these problems has been attained must be left to the discriminating world to decide. The bodies and the souls of books are measured adequately, in general, only by tests applied long after publication. In the meantime, the books of the Institution are growing in number and in variety, as may be seen from the statistical data furnished in a subsequent section of this report. It may be remarked also that intelligent interest in these books is now general and that the demand for them, especially from well-conducted libraries, is steadily increasing.

Distribution of Publications.

The matter of distribution of the publications of the Institution has presented many difficulties. These are due partly to inherited methods which are no longer suited to the conditions under which a research establishment may now exist, and partly to the prevalent impression that the Institution is under no economic restrictions in this as in other fields of its work. The methods referred to are methods of patronage. They have led to a division of owners of books into

two principal classes, namely: first, bibliophiles, or those who attach an undue personal value to books; and secondly, those who see in them no worth as property, arguing, apparently, that what costs nothing may be esteemed at the same value. Both classes, however, have the common property of assiduous solicitation. Quite a different set of difficulties is presented by learned societies and other organizations between which the custom long since arose of interchange of publications. But while this is practicable to an organization which issues a book only once a year, or perhaps once in five years, it may be quite impracticable to an establishment which is issuing from twenty to fifty volumes per year. Thus the Institution finds itself compelled to decline any such system of exchange for the simple reason that its entire income would be insufficient to meet the demands thereof.

Another sort of difficulty arises from the nearly universal assumption that a research organization must maintain a library; but since the headquarters of the Institution are located in the near vicinity of many efficient libraries, it would be a waste of resources to attempt to build up an additional one. In spite of this obvious fact, however, the Institution receives annually a large number of publications which are useful only as small numbers of them may be distributed to the working libraries of the departments of research.

An additional source of embarrassment arises from the unwarranted assumption that since the Institution is occupied with the business of research it may be able to look after the needs and requirements not only of technical societies and libraries but also anticipate and supply the needs of individual workers in science. Experience proves, however, that no such paternalistic functions are realizable. The number of individuals, societies, and organizations desiring such aid is far greater than any single establishment can deal with. Moreover, little short of omniscience would be required to determine, without the aid of the beneficiaries, what may be essential to satisfy their needs. Accumulated experience has tended to confirm the conclusion that the only practicable and stable plan for free distribution of the Institution's publications is the one adopted a decade ago, namely, that of supplying them to a limited list of the greater libraries of the

world. Each such library receives a full set of these publications, and additions thereto are promptly forwarded to each. Something less than three hundred libraries were originally selected for this Omnia List. It is subject to constant revision and extension, and now embraces about three hundred and twenty entries. Libraries found inefficient to the communities in which they are placed, or inattentive in acknowledging receipt of accessions from the Institution, are summarily dropped. It is a somewhat depressing fact that many libraries, still so-called, seem to exist only for the benefit of curators and bookbinders. On the other hand, the number of efficient libraries is now rapidly increasing, so that one who makes much use of books may no longer afford to own and to care for books if he is in the near vicinity of an efficient library.

To meet the needs of special societies and of individuals, as well as of certain establishments, like the British Museum, which quite rationally prefer to purchase publications instead of receiving them gratuitously, all of the Institution's publications are offered for sale at nominal prices, which are only just sufficient to cover the costs of bookmaking and transportation to purchasers. These prices are only about half as great as those which would be charged by commercial publishing houses for books of the same general character but printed on inferior or perishable paper. When the world comes to understand the economic advantages presented by this method of distribution by sale at cost, it will become practicable to promote the advancement of learning much more effectively than at present. Thus, for example, call is often made upon the Institution for the reproduction of books long out of print. Such reproduction may now be accomplished in a highly satisfactory manner by photographic processes, and it could be done in many cases without detriment to the other work of the Institution if the world were disposed to share the expense involved.

FINANCIAL RECORDS.

Financial Statement for Fiscal Year 1914-1915.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unallotted and unexpended at the end of the year are shown in detail in the following statement:

Object of appropriation.	Balances unallotted Oct. 31, 1914.	Appropriation Dec. 11, 1914.	Revertments Nov. 1, 1914, to Oct. 30, 1915.	Total.	Aggregates of allotments and amounts expended and transferred.	Balances unallotted Oct. 30, 1915
Large grants	....	$702,312.00	$12,118.21	$714,430.21	$714,430.21	....
Minor grants	$5,163.51	138,711.54	3,168.35	147,043.40	144,598.22	$2,445.18
Publication	16,420 19	60,000.00	4,123.22	80,543.41	73,148.66	7,394.75
Administration	....	50,000.00	7,000.00	57,000.00	57,000.00	....
Reserve fund	....	250,000 00	....	250 000 00	250,000.00	....
Insurance fund	....	25,000.00	....	25,000.00	25,000.00	....
Total	21,583.70	1,226,023.54	26,409.78	1,274,017.02	1,264,177.09	9,839.93

Summary of Receipts and Expenditures of the Institution to date.

The aggregates of receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by the following table; the grand total of these to date is $11,656,532.97.

Aggregates of financial receipts.

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
1902	$250,000.00	$9 70	....	....	$1,825.52	$251,835.22
1903	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905	500,000.00	25,698.59	3,038 95	200.94	150.00	529,088 48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944 73
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375.00	67,888 31	10,297.79	8,322.87	28,162.79	1,215,046.76
Total	9,883,814.17	376,848.75	103,964.03	35,266.08	*1,256,639.94	11,656,532.97

*Of this amount $1,215,500 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads: (1) investments in bonds; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The following table shows the actual expenditures under these heads for each year since the foundation of the Institution:

Purposes for which funds have been appropriated.

Year ending Oct. 31.	Investments in bonds.	Large projects.	Minor projects, special projects, research associates, and assistants.	Publications.	Administration.	Total
1902...	....	....	$4,500.00	....	$27,513 00	$32,013.00
1903...	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904..	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905...	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906...	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907...	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908...	68,209.80	448,404 65	61,282 11	49,991 55	48,274.90	676,163.01
1909...	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910...	57,889.15	437,941.40	73,464.63	49,067.00	44,011.61	662,373.79
1911...	51,921.79	463,609 75	63,048.80	37,580.17	45,455.80	661,616 31
1912...	436,276.03	519,673 94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913...	666,428.03	698,337 03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914..	861,915.73	817,894 52	107,456.05	44,670 55	44,159 54	1,876,096.39
1915...	206,203.21	770,488 58	109,569 37	46,698 56	48,224.04	1,181,183.76
Total.	2,879,187.31	5,853,681.37	1,391,603.29	507,399.63	596,705 99	11,228,577.59

The following list shows the departments of investigation to which the larger grants were made by the Trustees at their last annual meeting and the amounts allotted from these grants by the Executive Committee during the year:

Department of Botanical Research	$40,615.00
Department of Economics and Sociology	3,000 00
Department of Experimental Evolution	48,919.00
Geophysical Laboratory	89,164.00
Department of Historical Research	31,400.00
Department of Marine Biology	19,150.00
Department of Meridian Astrometry	26,380.00
Nutrition Laboratory	45,064.00
Division of Publications	10,000.00
Solar Observatory	220,130.00
Department of Terrestrial Magnetism	141,310.00
Department of Embryology	32,180.00
Total	707,312 00

The following statements show the fields of investigation to which minor grants were assigned, together with the names of the grantees and the amounts of the grants; also the grants for publications authorized during the year; and the sources and amounts of revertments from November 1, 1914, to October 31, 1915.

Details of minor grants.

Fields of investigation.	Names of grantees.	Amounts of grants.
Astronomy	Kapteyn, J. C.	$2,000.00
	Störmer, Carl	800.00
Archeology	Van Deman, E. B	1,800.00
	Morley, S. G	4,000.00
Bibliography	Index Medicus	13,500.00
Biology	Department of Experimental Evolution	500.00
	Jackson, R. T	350.00
	Morgan, T. H	3,300.00
	Vaughan, T. W	180.00
Botany	Britton, N. L., and J. N. Rose	8,000.00
	Clements, F. E	1,200.00
	Lloyd, F. E	400.00
	McCallum, W. B	300.00
	Dutra, J. C	100.00
Chemistry	Jones, H. C	2,200.00
	Morse, H. N	4,000.00
	Noyes, A. A	2,000 00
	Osborne, T. B., and L. B. Mendel	15,000.00
	Richards, T. W	3,000.00
	Sherman, H. C	1,200.00
Geology	Chamberlin, T. C	4,000.00
	Moulton, F. R	2,000.00
History	Andrews, C. M	1,000.00
	Bandelier, Fanny R	2,000.00
	Osgood, H. L	2,000.00
	Turner, Frederic J	3,600.00
Literature	Bergen, Henry	1,800.00
Mathematics	Morley, Frank	1,200.00
Meteorology	Bjerknes, V	1,800.00
Paleontology	Case, E. C	1,500.00
	Hay, O. P	3,000.00
	Wieland, G. R	3,000.00
Paleography	Loew, E. A	1,800.00
Philology	Churchill, William	5,048.00
Physics	Barus, Carl	500.00
	Howe, H. M	500.00
	Nichols, E. L	3,000.00
Physiology	Reichert, E. T	3,000.00
Zoology	Castle, W. E	2,500.00
	Naples Zoological Station	1,000.00
Exhibit at Panama-Pacific International Exposition		1,000.00
Department of Terrestrial Magnetism (insurance)		200.00
Administration Building (additions)		320.22
		109,598.22

Grants for publications authorized during the year.

Barus, Carl	$1,400.00
Bauer, L. A., and J. A. Fleming	447.12
Benedict, F. G., and H. Murschhauser	700.00
Benedict, F. G., and F. B. Talbot	1,000.00
Carnegie Institution of Washington Pamphlets	1,550.00
Carpenter, T. M	1,700.00
Case, E. C	471.89
Clark, Victor S	3,500.00
Clark, E. R., J. C. Watt, A W. Meyer, G. W. Corner, C. R. Essick	650.00
Concordance to Keats	4,500.00
Crampton, H. E	9,000.00
Davenport, C. B	1,600.00
Dodge, R., and F. G. Benedict	1,700.00
Duesberg, J., F. R. Sabin, P. G. Shipley, G. B. Wislocki	2,280.61
Faust, A. B	1,200.00
Hale, G. E	701.50
Hill, R. R	2,600.00
Howard, L. O	1,265.45
Johnson, D. S., and H. H. York	2,400.00
Johnson, E. R., *et al*	4,000.00
Jones, H. C	1,800.00
Knobel, E. B., and C. H. F. Peters	2,000.00
Moodie, R. L	3,500.00
Morley, S. G	3,000.00
Morgan, T. H., and C. B. Bridges	1,400.00
Papers from Department of Marine Biology	5,032.09
Reprint of "The Old Yellow Book"	1,500.00
Reprint of "Star Catalogue" by Lewis Boss	1,100.00
Richards, H. M	800.00
Shreve, Forrest	1,600.00
Sommer, H. O	500.00
Stout, A. B	1,250.00
Watson, J. B	1,400.00
Wieland, G. R	5,600.00
	73,148.66

Sources and amounts of revertments from Nov. 1, 1914, to Oct. 31, 1915.

Large grants:		
Revertment from minor grants	$5,000.00	
Department of Experimental Evolution, unappropriated	4,618.21	
Division of Publications, unappropriated	1,000.00	
Department of Meridian Astrometry	1,500.00	
Minor grants:		$12,118.21
Administration additions, Grant No. 946	1.00	
Mahan, Alfred T., Grant No. 932	1,600.00	
Work of L. Burbank, Grant No. 658	17.35	
Mark, E. L., Grant No. 506	300.00	
Brigham, W. T., Grant No. 341	1,250.00	
Publications:		3,168.35
Marine Biology, Grant No. 884	152.74	
Detlefsen, J. A., Grant No. 962	455.70	
Mayer, A. G., Grant No. 953	298.64	
Benedict, F. G., Grant No. 961	99.44	
Jones, H. C., Grant No. 963	333.07	
Livingston, B. E., Grant No. 966	40.28	
Carnegie Institution of Washington, Grants Nos. 970 and 971	168.95	
Mall, F. P., Grant No. 967	33.00	
Richards, H. M., Grant No. 1027	114.61	
Marine Biology, Grant No. 975	12.53	
Marine Biology, Grant No. 1028	513 40	
Carpenter, T. M., Grant No. 1034	289.26	
Embryology, Grant No. 968	494.04	
Benedict, F. G., *et al.*, Grant No. 1042	188.08	
Stout, A. B., Grant No. 1031	114.54	
Jones, H. C., *et al.*, Grant No. 1045	814.94	
Administration:		4,123.22
Revertment from allotted balance		7,000.00
		26,409.78

Investments in Property.

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended:

Schedule of real estate, equipments, and publications.

Administration:		
Building, site, and equipment		$332,179.61
Publications:		
Stock on hand (Oct. 30, 1915)	$236,594.35	
Outstanding accounts (Oct. 31, 1915)	1,981.05	
		238,575.40
Department of Botanical Research (Sept. 30, 1915):		
Buildings, office, and operating	49,385.10	
Laboratory equipment	12,063.21	
		61,448.31
Department of Experimental Evolution (Sept. 30, 1915):		
Buildings, office, and library	103,149.20	
Laboratory apparatus	7,248.25	
Operating appliances and grounds	19,897.95	
		130,295.40
Geophysical Laboratory (Sept. 30, 1915):		
Building, library, operating appliances	120,524.84	
Laboratory apparatus	75,832.81	
Shop equipment	15,084.66	
		211,442.31
Department of Historical Research (Sept. 30, 1915):		
Office	2,030.33	
Library	2,908.16	
		4,938.49
Department of Marine Biology (Sept. 30, 1915):		
Vessels	32,325.40	
Buildings, docks, furniture, and library	11,651.96	
Apparatus and instruments	4,981.94	
		48,959 30
Department of Meridian Astrometry (Sept. 30, 1915):		
Apparatus and instruments	2,394.34	
Operating	1,277.62	
		3,671.96
Nutrition Laboratory (Sept. 30, 1915):		
Building, office, and shop	117,200.15	
Laboratory apparatus	20,827.26	
		138,027.41
Mount Wilson Solar Observatory (Aug. 31, 1915):		
Buildings, grounds, road, and telephone line	196,193.06	
Shop equipment	37,129.26	
Instruments	394,460.17	
Furniture and operating appliances	84,483.28	
Hooker 100-inch reflector	371,219.66	
		1,083,485.43
Department of Terrestrial Magnetism (Sept. 30, 1915):		
Building, site, and office	131,616.33	
Vessel and survey equipment	129,417.12	
Instruments, laboratory, and shop equipment	55,088.21	
		314,121.66
		2,567,145.28

Expenses of Maintenance of Administration Building.

The cost of maintenance of the Administration Building, including the items of fuel, lighting, janitorial services, maintenance of grounds, repairs, and other incidental expenses, has been, for 1910, $2,981.65; for 1911, $2,641.53; for 1912, $2,919.89; for 1913, $2,601.15; for 1914, $3,251.08, and for 1915, $3,955.60.

Repairs to Administration Building.

During the past summer the underground intake pipe from the street water-main sprung a leak under the floor of the basement of the Administration Building. Such underground pipes are required by the building regulations of the District of Columbia to be of lead, and although the material used at the time of the construction of the building was of the highest quality, it appears to be inadequate to meet the maximum pressures communicated from the street mains. A similar break occurred in 1910, but its location on that occasion was easily found and repair was made without the necessity of removing any of the concrete floors. In the case of the recent break, however, it appeared essential to remove a considerable portion of these floors in order to find and to repair the break. Since immediate action was necessary it was determined to substitute for the underground intake an overhead system of galvanized-iron pipes. This was quickly installed at a cost of $324. During the past summer also the masonry joints of the entire building have been carefully examined and repointed where necessary. Some additional fenders have been supplied on the walls of the east side of the building in order to prevent damage from heavily loaded freight wagons. The expense of these repairs and alterations has required no special appropriation aside from the usual item for repairs contained in the budget for 1915.

PUBLICATIONS.

Publications Authorized and Issued during the Year.

The publication of 35 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $73,148.66. The following list gives the titles and names of the authors of the publications issued during the year; it includes 23 volumes, with an aggregate of 4,686 octavo pages and 1,466 quarto pages; 45 additional volumes are now in press.

List of publications issued during the year.

Year Book, No. 13, 1914. Octavo, xvi+399 pages, 7 plates.

Index Medicus, Second Series, vol. 12, 1914. Octavo, 1,526 pages.

No. 85. Hasse, Adelaide R. Index of Economic Material in the Documents of the States of the United States. Prepared for and under the direction of the Department of Economics and Sociology of the Carnegie Institution of Washington. Separate volume for each State. New Jersey (1789–1904). Quarto, 705 pages.

No. 159. Howard, L. O., Harrison G. Dyar, and Frederick Knab. The Mosquitoes of North and Central America and the West Indies. In 4 volumes. Vol. 3. Description of Species. Octavo, vi+523 pages.

No. 175. Bauer, L. A., and J. A. Fleming. Land Magnetic Observations, 1911–1913, and Reports on Special Researches. (Researches of the Department of Terrestrial Magnetism.) Vol. 2. Quarto, v+278 pages, 13 plates, 9 figures.

No. 203. Benedict, Francis G. A Study of Prolonged Fasting. Octavo, 416 pages, 5 plates, 47 figures.

No. 204. Livingston, B. E., and L. A. Hawkins. The Water Relation between Plant and Soil. Octavo, pages 1–48, 3 figures.
Pulling, H. E., and B. E. Livingston. The Water-Supplying Power of the Soil as Indicated by Osmometers. Octavo, pages 49–84, 2 figures.

No. 205. Detlefsen, J. A. (With prefatory note by W. E. Castle.) Genetic Studies on a Cavy Species Cross. (Paper No. 23, Station for Experimental Evolution.) Octavo, 134 pages, 10 plates, 2 text figures.

No. 207. Case, E. C. The Permo-Carboniferous Red Beds of North America and their Vertebrate Fauna. Quarto, 176 pages, 24 plates, 50 figures.

No. 209. Richards, Herbert M. Acidity and Gas Interchange in Cacti. Octavo, 107 pages, 6 text figures.

No. 210. Jones, Harry C., and Collaborators. The Absorption Spectra of Solutions as Studied by Means of the Radio-micrometer. The Conductivities, Dissociations, and Viscosities of Solutions of Electrolytes in Aqueous, Non-Aqueous, and Mixed Solvents. Octavo, 202 pages, 1 plate, 58 text figures.

No. 211. Papers from the Department of Marine Biology of the Carnegie Institution of Washington. Octavo, 128 pages, 9 plates, 19 figures.

No. 212. Papers from the Department of Marine Biology of the Carnegie Institution of Washington. Octavo, 261 pages, 23 plates, 73 figures.

No. 216. Carpenter, Thorne M. A Comparison of Methods for Determining the Respiratory Exchange of Man. Octavo, 265 pages, 74 figures.

No. 217. Shreve, Forrest. The Vegetation of a Desert Mountain Range as Conditioned by Climatic Factors. Octavo, 112 pages, 37 plates, 18 figures.

No. 218. Stout, A. B. The Establishment of Varieties in Coleus by the Selection of Somatic Variations. Octavo, 80 pages, 4 plates, 1 text figure.

No. 221. Mall, Franklin P. On the Fate of the Human Embryo in Tubal Pregnancy. (Contribution to Embryology No. 1.) Quarto, 104 pages, 11 plates, 24 text figures.

No. 222. Contributions to Embryology, Nos. 2, 3, 4, 5, and 6. Quarto, 108 pages, 10 plates, 25 figures.

No. 223. Contributions to Embryology, Nos. 7, 8, and 9. Quarto, 90 pages, 12 plates, 12 figures.

No. 230. Jones, Harry C., and Collaborators. Conductivities and Viscosities in Pure and in Mixed Solvents: The Radiometric Measurements of the Ionization Constants of Indicators. Octavo, VIII+175 pages, 21 figures.

No. 231. Benedict, F. G., and H. Murschhauser. Energy Transformations during Horizontal Walking. Octavo, 100 pages, 7 figures.

No. 235. Hale, George E. Ten Years' Work of a Mountain Observatory: A Brief Account of the Mount Wilson Solar Observatory. 12mo, 99 pages, 65 text figures.

Souvenir Pamphlet. Fourth Issue. For distribution at the Panama-Pacific International Exposition. 45 pages.

Sales of Publications and Value of those on hand.

The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903	$2,256.91	$29.25	......
1904	2,370.47	52.85	$12.75
1905	2,562.76	44.75	431.44
1906	2,970 56	37.60	1,341.52
1907	3,676.71	56.50	2,292.89
1908	3,406.19	99.65	4,371.67
1909	4,821.85	73.01	6,287.21
1910	4,470.50	100.70	5,899.05
1911	4,440.21	85.50	6,366.55
1912	4,652.14	61.65	6,782.34
1913	4,992.02	75.95	7,140.69
1914	5,079.16	49.65	6,273.59
1915	5,010.21	47.60	5,239.98
Total	50,709.69	814.66	52,439.68

At the end of the fiscal year just closed there are on hand 95,585 volumes of miscellaneous publications and Year Books, having a sale value of $221,107.60; also 30,428 numbers of the Index Medicus, having a sale value of $15,486.75. The total value of publications on hand is therefore $236,594.35.

In connection with the above statement it is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, a total of 143,896 volumes of publications of the Institution.

Growth and Extent of Institution's Publications.

The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. Two hundred and ninety-nine volumes, embracing a total of more than 79,000 pages of printed matter, have thus far been issued by the Institution.

Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the fourteen years from 1902 to 1915.

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902	3	46	....	46
1903	3	1,667	....	1,667
1904	11	2,843	34	2,877
1905	21	3,783	1,445	5,228
1906	19	3,166	1,288	4,454
1907	38	6,284	3,428	9,712
1908	28	4,843	2,485	7,328
1909	19	3,695	1,212	4,907
1910	29	3,274	4,831	8,105
1911	30	5,062	1,670	6,732
1912	23	3,981	2,044	6,025
1913	29	6,605	2,752	9,357
1914	23	4,978	1,934	6,912
1915	23	4,686	1,466	6,152
Total...	299	54,913	24,589	79,502

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK OF INVESTIGATORS, ASSOCIATES, AND COLLABORATORS.

Under this heading it is sought to include titles of all publications bearing upon work done under the auspices of the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 27, 28).

Adams, L. H. Some notes on the theory of the Rayleigh-Zeiss interferometer. Jour. Wash. Acad. Sci., vol. 5, 265–276 (1915).

———. The use of the interferometer for the analysis of solutions. Jour. Amer. Chem. Soc., vol. xxxvii, 1181–1194 (1915).

———. The measurement of the freezing-point depression of dilute solutions. Jour. Amer. Chem. Soc., vol. xxxvii, 481–496 (1915).

Adams, Walter S. Three stars with bright hydrogen lines. Pubs. A. S. P., vol. 26, 260 (1914).

———. Ten spectroscopic binaries. Pubs. A. S. P., vol. 26, 261 (1914).

———. Seven spectroscopic binaries. Pubs. A. S. P., vol. 27, 132 (1915).

———. Three stars with great radial velocities. Pubs. A. S. P., vol. 27, 132 (1915).

———. The radial velocities of the more distant stars. Proc. Nat. Acad. Sci., vol. 1, 417 (1915). Mt. Wilson Communications, No. 13; read at 18th meeting, Amer. Astron. Soc. (1915).

———. The radial velocities of five hundred stars. Astrophys. Jour., vol. xlii, 172–194 (1915); Mt. Wilson Contr., No. 105.

——— and Cora G. Burwell. The flash spectrum without an eclipse. Region λ 4800 to λ 6600. Astrophys. Jour., vol. xli, 116 (1915); Mt. Wilson Contr., No. 95.

———, ———. Results of an investigation of the flash spectrum without an eclipse. Proc. Nat. Acad. Sci., vol. 1, 127 (1915); Mt. Wilson Communications, No. 4.

———, and Francis G. Pease. The spectra of ten stars of very low luminosity. Pubs. A. S. P., vol. 26, 258 (1914).

———, ———. The spectrum of T Tauri. Pubs. A. S. P., vol. 27, 132 (1915).

———, ———. Nova Geminorum No. 2 as a Wolf-Rayet star. Proc. Nat. Acad. Sci., vol. 1, 391 (1915); Mt. Wilson Communications, No. 12.

———. See Kapteyn, J. C.

———. See St. John, Charles E.

Albrecht, Sebastian. On systematic errors of stellar radial velocities. Astrophys. Jour., vol. xl, No. 5 (Dec. 1914).

———. Anomalous dispersion in the Sun. Astrophys. Jour., vol. xli, No. 5 (June 1915).

Allen, E. T. See Posnjak, Eugen.

von Alten. Ueber die Entwicklung des Keimendarms bei Schildkröten. Ber. d. naturförsch. Gesellsch. zu Freiburg im Breisgau, vol. xx (1914).

Anderegg, F. A. See Richards, Theodore W.

Andersen, Olaf. The system anorthite-forsterite-silica. Amer. Jour. Sci. (4), vol. xxxix, 407–454 (1915).

———. Das ternäre System: Anorthit-Forsterit-Silicium-2-Oxyd. Neues Jahr. Min. Geol. (in press).

———. On aventurine feldspar. Amer. Jour. Sci. (4), vol. xl, 351–398 (1915). Aventurine Feldspate. Z. Kryst. (in press).

Ault, J. P. Magnetic declinations and chart corrections obtained by the *Carnegie* from Brooklyn, New York, to Colon, Panama, March 1915, and from Balboa, Canal Zone, to Honolulu, Hawaii, March–May 1915. Terr. Mag., vol. 20, No. 2, 69–70 (June 1915). Washington.

———. Magnetic declinations and chart corrections obtained by the *Carnegie* from Honolulu, Hawaii, to Dutch Harbor, Alaska, June–July 1915. Terr. Mag., vol. 20, No. 3, 104 (Sept. 1915). Washington. See Bauer, L. A.

Babcock, Harold D. Review of laboratory studies of the Zeeman effect at Mt. Wilson Solar Observatory. Read at joint meeting, Amer. Assn. Adv. Sci. and affiliated societies (1915).

———. See Hale, George E.

———. See St. John, Charles E.

Bakke, A. L. Studies on the transpiring power of plants as indicated by the method of standardized hygrometric paper. Jour. Ecol., vol. 2, 145–173 (1914).

Banta, A. M. The effects of long-continued parthenogenetic reproduction (127 generations) upon daphnids. Science, n. s., vol. xli, 442 (Mar. 19, 1915).

———. Some notes on albinism. Science, n. s., vol. xli, 577–578 (Apr. 16, 1915).

———, and R. A. Gortner. A milky white amphibian egg jell. Biol. Bull., vol. 27, 259–261 (Nov. 1914).

———, ———. Accessory appendages and other abnormalities produced in amphibian larvæ through the action of centrifugal force. Jour. Exper. Zool., vol. 18, 433–451 (Apr. 1915).

———, ———. An albino salamander, *Spelerpes bilineatus*. Proc. U. S. Nat. Mus., vol. xlix, 377–379, pls. 54, 55 (Aug. 1915).

BARRY, FREDERICK. See RICHARDS, THEODORE W.

BARUS, CARL. Mutual repulsion of rigid parallel plates, II. Amer. Jour. Sci., vol. XXXIX, 93–104 (1915).

———. The use of compensators, bounded by curved surfaces, in displacement interferometry. Amer. Jour. Sci., vol. XL, 299–308 (Sept. 1915).

———. The mathematician in modern physics. Science, n. s., vol. XL, 721–727 (1914).

———. Contractions of the order of the Lorentz-Fitzgerald effect. Amer. Jour. Sci., vol. XXXVIII, 352–354 (1914).

BATEMAN, H. On the mean value of a function of spherical polar coordinates round a circle on a sphere. Terr. Mag., vol. 20, 127–129 (Sept. 1915). Washington.

BAUER, L. A. The Earth's magnetism. The fourth "Halley Lecture," delivered in the schools of the University of Oxford on May 22, 1913; illustrated by lantern slides. Reprinted, after revision by the author and with added illustrations, from Bedrock, vol. 2, No. 3, 273–294 (Oct. 1913); in Annual Report of Board of Regents of Smithsonian Institution for year ending June 30, 1913. Smithsonian Inst. Pub. 2281, 195–212, 9 pls. (1914). Washington.

———. Department of Terrestrial Magnetism of the Carnegie Institution of Washington. 5 pages, 3 pls., map (Dec. 11, 1914). Washington.

———. General results of the work in atmospheric electricity aboard the *Carnegie*, 1909–1914. Proc. Amer. Phil. Soc., vol. 54, No. 216, 14–17 (Jan.–Apr. 1915). Philadelphia.

———. Magnetic inspection trip and observations during total solar eclipse of April 28, 1911, at Manua, Samoa. Reprinted from Land Magnetic Observations 1911–1913 and Reports on Special Researches. Researches of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, Pub. No. 175, vol. II, 201–209, 1 pl. (1915). Washington.

———, and J. P. AULT. Magnetic declinations and chart corrections obtained by the *Carnegie* from Hammerfest, Norway, to Reykjavik, Iceland, and thence to Brooklyn, New York, July to October 1914. Terr. Mag., vol. 19, No. 4, 234–235 (Dec. 1914). Washington.

———, ———. Results of comparisons of magnetic standards, 1905–1914. Reprinted from Land Magnetic Observations 1911–1913 and Reports on Special Researches. Researches of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, Pub. 175, vol. II, 211–278, 3 pls. (1915). Washington.

———, and W. J. PETERS. Magnetic declinations and chart corrections obtained by the *Carnegie* from Bahia, Brazil, to St. Helena, May 20 to June 22, 1913. Terr. Mag., vol. 19, No. 4, 204 (Dec. 1914). Washington.

General results of the magnetic survey of the Pacific Ocean. Terr. Mag., vol. 20, 95–103 (Sept. 1915). Washington.

BAXTER, GREGORY P. A search for an alkali element of higher atomic weight than cæsium. Jour. Amer. Chem. Soc., vol. XXXVII, 286–288 (1915); Zeit. für anorg. Chem., Bd. 92, 24–26 (Feb. 1915).

———, and MERRITT, R. GROSE. The vapor pressure of iodine between 50° and 95°. Jour. Amer. Chem. Soc., vol. XXXVII, 1061–1072 (May 1915).

———, and FRED L. GROVER. The resistance of platinum vessels to hot nitric acid. Jour. Amer. Chem. Soc., vol. XXXVI, 1089–1091 (June 1914); Zeit. für anorg. Chem., Bd. 87, 353–356 (Apr. 1914).

———, ———. A revision of the atomic weight of lead. The analysis of lead bromide and chloride. Jour. Amer. Chem. Soc., vol. XXXVII, 1027–1061 (May 1915).

and T. THORVALDSON. A revision of the atomic weight of lead. The analysis of lead bromide and chloride. Proc. Nat. Acad. Sci., vol. 1, 71–77 (Feb. 1915).

———, and M. L. HARTMANN. A revision of the atomic weight of cadmium. Proc. Nat. Acad. Sci., vol. 1, 26–29 (Jan. 1915).

———, ———. A revision of the atomic weight of cadmium. III: The electrolytic determination of cadmium in cadmium chloride. Jour. Amer. Chem. Soc., vol. XXXVII, 113–131; Zeit. anorg. Chem., Bd. 92, 53–75 (Jan. 1915).

———, and OLUS J. STEWART. A revision of the atomic weight of praseodymium. Proc. Nat. Acad. Sci., vol. 1, 77–80 (Feb. 1915).

———, ———. A revision of the atomic weight of praseodymium. The analysis of praseodymium chloride. Jour. Amer. Chem. Soc., vol. XXXVII, 516–536 (Mar. 1915); Proc. Amer. Acad. Arts and Sciences, vol. L, 171–195 (Feb. 1915); Zeit. für anorg. Chem., Bd. 92, 171–197 (Mar. 1915).

———, and T. THORVALDSON. A revision of the atomic weight of lead. The analysis of lead bromide. Jour. Amer. Chem. Soc., vol. XXXVII, 1020–1027 (May 1915).

BEITLER, FREDERIC V. Still-born children: what the term includes; estimation of occurrence; value of registration. State Board of Health of Maryland, pamphlet (1914).

BENEDICT, FRANCIS G. Chemical and physiological studies of a man fasting 31 days. Proc. Nat. Acad. Sci., vol. 1, 228 (1915).

———. Factors affecting basal metabolism. Jour. Biol. Chem., vol. XX, 263 (1915).

———. The factors affecting normal basal metabolism. Proc. Nat. Acad. Sci., vol. 1, 105 (1915).

BENEDICT, FRANCIS G. A respiration apparatus for small animals. Jour. Biol. Chem., vol. XX, 301 (1915).
———. Investigations at the Nutrition Laboratory of the Carnegie Institution of Washington, Boston, Massachusetts. Science, n. s., vol. XLII, 75 (1915).
———, and LOUIS E. EMMES. A comparison of the basal metabolism of normal men and women. Jour. Biol. Chem., vol. XX, 253 (1915).
———, ———. A comparison of the basal metabolism of normal men and women. Proc. Nat. Acad. Sci., vol. 1, 104 (1915).
———, ———. A calorimetric calibration of the Krogh bicycle ergometer. Amer. Jour. Physiol., vol. XXXVIII, 52 (1915).
———, and PAUL ROTH. The metabolism of vegetarians as compared with the metabolism of non-vegetarians of like weight and height. Jour. Biol. Chem., vol. XX, 231 (1915).
———, ———. The basal caloric output of vegetarians as compared with that of non-vegetarians of like weight and height. Proc. Nat. Acad. Sci., vol. 1, 100 (1915).
———, and H. MONMOUTH SMITH. The metabolism of athletes as compared with normal individuals of similar height and weight. Jour. Biol. Chem., vol. XX, 243 (1915).
———, ———. The influence of athletic training upon basal metabolism. Proc. Nat. Acad. Sci., vol. 1, 102 (1915).
BLAKESLEE, ALBERT F. Sexual reactions between hermaphroditic and diœcious mucors. Biol. Bull., vol. XXIX, 87–96, pls. 1–3 (Aug. 1915).
———. Linder's roll tube method of separation cultures. Phytopath., vol. 5, 68–70, pl. VII (Feb. 1915).
———, and R. A. GORTNER. Reaction of rabbits to intravenous injections of mold spores. Biochem. Bull., vol. IV, 45–51, pl. 2 (Mar. 1915).
BOWEN, N. L. The crystallization of haplobasaltic, haplodioritic, and related magmas. Amer. Jour. Sci. (4), vol. XL, 161–185 (1915).
———. Das ternäre System Diopsid-Anorthit-Albit. Z. anorg. Chem. (in press).
———. Crystallization-differentiation in silicate liquids. Amer. Jour. Sci. (4), vol. XXXIX, 175–191 (1915).
BROWN, J. G. The effect of desiccation upon structure of *Echinocactus wislizeni*. Physiol. Researches, vol. 1, No. 7, 316–325 (1915).
BURNETT, E. C. See LELAND, W. G.
BURWELL, CORA G. See ADAMS, WALTER S.
CANNON, W. A. On the relation of root growth and development to the temperature and aëration of the soil. Amer. Jour. Bot., vol. II, 211 (May 1915).
CARY, L. R. The Alcyonaria as a factor in reef limestone formation. Proc. Nat. Acad. Sci., vol. 1, 285–289 (1915).
CASE, E. C. On the structure of the inner ear in two primitive reptiles. Biol. Bull., vol. XXVII, No. 4 (1914).
CASTLE, W. E. Bateson's address, Mendelism, and mutation. Science, n. s., vol. XLI, 94–98 (Jan. 15, 1915).
———. Mr. Muller on the constancy of Mendelian characters. Amer. Nat., vol. 49, 37–42 (Jan. 1915).
———. Selection, sugar beets and thrips. Amer. Nat., vol. 49, 121–122 (Feb. 1915).
———, and H. D. FISH. The black-and-tan rabbit and the significance of multiple allelomorphs. Amer. Nat., vol. 49, 87–96 (Feb. 1915).
———, and PHILIP B. HADLEY. The English rabbit and the question of Mendelian unit-character constancy. Amer. Nat., vol. 49, 22–27 (Jan. 1915); Proc. Nat. Acad. Sci., vol. 1, 39–43 (Jan. 1915).
———, and SEWALL WRIGHT. Two color mutations of rats which show partial coupling. Science, n. s., vol. XLII, 193–195 (Aug. 6, 1915).
CHURCHILL, WILLIAM. The earliest Samoan prints. Proc. Academy of Natural Sciences of Philadelphia, 199–202 (Apr. 1915).
CLARK, ELEANOR LINTON. Observations of the lymph-flow and the associated morphological changes in the early superficial lymphatics of chick embryos. Anat. Rec., vol. IX, 65–67 (1915).
———, and ELIOT R. CLARK. On the early pulsations of the posterior lymph hearts in chick embryos; their relation to the body movements. Jour. Exper. Zool., vol. XVII, 373–394 (1914).
CLARK, ELIOT R. Studies of the growth of blood-vessels, by observations of living tadpoles and by experiments on chick embryos. Anat. Rec., vol. IX, 67 (1915).
———. The lymphatic system. Morris and Jackson's Anatomy, 5th ed. (1914). Philadelphia.
———. See CLARK, ELEANOR LINTON.
COBLE, ARTHUR B. Point sets and allied Cremona groups. Proc. Nat. Acad. Sci., 245–248 (Apr. 1915).
———. Point sets and allied Cremona groups, Part I. Trans. Amer. Math. Soc., 155–198 (Apr. 1915).
COLBY, WALTER. Signal propagation in dispersive media. Phys. Rev., ser. 2, vol. 5, 253 (1915).
COOMBS, LESLIE B. See RICHARDS, THEODORE W.

Conner, J. R. The rational space sextic curve and the Cayley symmetroid. Amer. Jour. Math. (Apr. 1915).

Cowdry, E. V. The comparative distribution of mitochondria in spinal ganglion cells of vertebrates. Amer. Jour. Anat., vol. xvii, 1–24 (1914).

———. The vital staining of mitochondria with janus green and diethylsafranin in human blood cells. Internat. Monatschr. f. Anat. u. Physiol., vol. xxxi, 267–286 (1914).

Cunningham, R. S. On the development of the lymphatics in the lungs of the pig. Anat. Rec., vol. ix, 69 (1915).

Davenport, C. B. Skin color of mulattoes. Jour. Heredity, vol. v, 556–558 (Dec. 1914).

———. The feebly inhibited: I. Violent temper and its inheritance. Proc. Nat. Acad. Sci., vol. 1, 37–38 (Jan. 1915).

———. The feebly inhibited: II. Nomadism or the wandering impulse; with special reference to heredity. Proc. Nat. Acad. Sci., vol. 1, 120–122 (Feb. 1915).

———. The feebly inhibited: III. Inheritance of temperament; with special reference to twins and suicides. Proc. Nat. Acad. Sci., vol. 1, 456–459 (Aug. 1915).

———. The value of scientific genealogy. Science, n. s., vol. xli, 337–342 (Mar. 5, 1915).

———. The racial element in national vitality. Pop. Sci. Mon., vol. lxxxvi, 331–333 (Apr. 1915).

———. A dent in the forehead. Jour. of Heredity, vol. vi, 163, 164 (Apr. 1915).

———. Huntington's chorea in relation to heredity and eugenics. Proc. Nat. Acad. Sci., vol. 1, 283–285 (May 1915).

———. Health and heredity. In Educational Hygiene, by L. W. Rapeer, 45–58 (1915). New York.

Davis, Daniel. A simple apparatus for microscopic and macroscopic photography. Anat. Rec., vol. ix (1915).

Davis, P. B. Some new forms of apparatus: A substitute for the twin-bulb traps in toluene mercury thermoregulators. Jour. Amer. Chem. Soc., vol. xxxvii, 1198, 1199 (May 1915).

———, and L. G. Pratt. A new form of pycnometer for liquids. Jour. Amer. Chem Soc., vol. xxxvii, 1199–1200 (May 1915).

———. See Jones, Harry C.

Day, Arthur L., and E. S. Shepherd. Water and volcanic activity. Smithsonian Report for 1913, 275–305.

———, R. B. Sosman, and J. C. Hostetter. Die Bestimmung der Dichte von Mineralien und Gesteinen bei hohen Temperaturen. Neues Jahr. Min. Geol., Beilage Bd. 40, 119–162 (1915).

See Washington, H. S.

Dockeray, F. C. Volumetric determination of the parts of the brain in a human fetus 156 mm. long (crown-rump), Anat. Rec., vol. ix, 207–211 (1915).

Donnan, Elizabeth. Papers of James A. Bayard. Vol. ii of Ann. Rep. Amer. Hist. Assn. for 1913.

Emmes, Louis E. See Benedict, Francis G.

Evans, Herbert M. The macrophages of mammals. Amer. Jour. Physiol., vol. xxxvii, 243–258 (1915).

———. An appeal to physicians for embryological material. (Printed privately.) 4to (1914).

———, and Werner Schulemann. Ueber Natur und Genese der durch saure Farbstoffe entstehenden Vitalfarbungsgranula. Folia Hæmatol., vol. xix, 207–219 (1915).

Fish, H. D. On the progressive increase of homozygous brother-sister matings. Amer. Nat., vol. 48, 759–761 (Dec. 1914).

———. See Castle, W. E.

Fleming, J. A., and W. F. Wallis. Latest annual values of the magnetic elements at observatories. Terr. Mag., vol. 20, 131–135 (Sept. 1915). Washington.

———. See Bauer, L. A.

Franz, S. I. Physiology of the brain. Refer. Handbook Med. Sci., vol. 2, 397–412 (1913).

———. The functions of the cerebrum. Psychol. Bull., vol. xi, 131–140 (1914).

———. Symptomatological differences associated with similar cerebral lesions in the insane. Psychological Monograph, No. 81, 1–79 (Apr. 1915).

———. The variations in distribution of the motor centers. Psychological Monograph, No. 81, 80–162 (Apr. 1915).

Friedmann, A. See Hesselberg, Th.

Gortner, R. A. See Banta, A. M.

———. See Blakeslee, A. F.

———. See Harris, J. A.

Grose, Merritt R. See Baxter, Gregory P.

Grover, Fred. L. See Baxter, Gregory P.

Gudger, E. W. The natural history of the whale shark, *Rhinodon typus* Smith. New York Zoologica, vol. 1, No. 19, 349–389 (Mar. 1915).

———. The gland of the clasper in sharks. Science, n. s., vol. xli, No. 1055, 436–437 (Mar. 19, 1915).

GUDGER, E. W. Utero gestation in the sharp-nosed shark, *Scoliodon terranovæ*. Science, n. s., vol. XLI, 439 (1915).

HADLEY, PHILIP B. See CASTLE, W. E.

HALE, GEORGE E. National academies and the progress of research. III: The future of the National Academy of Sciences. Science, n. s., vol. XL, 907 (1914), and vol. XLI, 12 (1915).

———. The Proceedings of the National Academy as a medium of publication. Science, n. s., vol. XLI, 815 (1915).

———. The direction of rotation of sun-spot vortices. Proc. Nat. Acad. Sci., vol. 1, 382 (1915); Mt. Wilson Communications, No. 10.

———. The work of a modern observatory. Pubs. A. S. P., vol. 27, 161 (1915); read at joint meeting, Amer. Assn. Adv. Sci. and affiliated societies (1915).

———, and HAROLD D. BABCOCK. An attempt to measure the free electricity in the Sun's atmosphere. Proc. Nat. Acad. Sci., vol. 1, 123 (1915); Mt. Wilson Communications, No. 3.

———, and GEORGE P. LUCKEY. Some vortex experiments bearing on the nature of sun-spots and flocculi. Proc. Nat. Acad. Sci., vol. 1, 385 (1915); Mt. Wilson Communications, No. 11.

HARRIS, J. ARTHUR. On the correlation between somatic characters and fertility. II: Illustrations from *Phaseolus vulgaris*. Amer. Jour. Bot., vol. 1, 398–411, diagrams 1–4 (Oct. 1914).

———. Pearson's tables for statisticians and biometricians. Science, n. s., vol. XL, 598–599 (1914).

———. Further observations on the relationship between the number of ovules formed and the number of seeds developing in *Cercis*. Bull. Torr. Bot. Club, vol. 41, 533–549, figs. 1–4 (Nov. 1914).

———. On spurious values of intra-class correlation coefficients arising from disorderly differentiation within the classes. Biometrika, vol. 10, 412–416 (1914).

———. The influence of position in the pod upon the weight of the bean seed. Amer. Nat., vol. 49, 44–47, figs. 1–3 (Jan. 1915).

———. On a criterion of substratum homogeneity or heterogeneity in field experiments. Amer. Nat., vol. 49, 430–454, figs. 1–3 (July 1915).

———. Physical conformation of cows and milk yield. Jour. Hered., vol. 6, 348–350 (Aug. 1915). (Explanation of figures supplied by editor without submitting proof.)

———, and ROSS AIKEN GORTNER, with collaboration of JOHN V. LAWRENCE. Studies in the physico-chemical properties of vegetable saps. III: A comparison of the physico-chemical constants of the juices expressed from the wall and from the included carpellary whorl in proliferous fruits of *Passiflora gracilis*. Biochem. Bull., vol. 4, 52–79, pl. 3 (Mar. 1915).

———, JOHN V. LAWRENCE, and ROSS AIKEN GORTNER. On the osmotic pressure of the juices of desert plants. Science, n. s., vol. XL, 656–658, 1 fig. (Apr. 1915).

HARTMANN, MINER L. See BAXTER, GREGORY P.

HARVEY, E. NEWTON. Cell permeability for acids. Internationale Zeit. für phys.-chem. Biol., Bd. I, 463–478 (1914).

HAY, OLIVER P. The Pleistocene mammals of Iowa. Iowa Geol. Sur., vol. XXIII, 1–662, pls. L–LXXV, figs. 1–142 (1914).

———. Contributions to the knowledge of the mammals of the Pleistocene of North America. Proc. U. S. Nat. Mus., vol. XLVIII, 515–575, pls. XXX–XXXVII (Apr. 8, 1915).

HERTZSPRUNG, EJNAR. Effective wave-lengths of 184 stars in the cluster N. G. C. 1647. Astrophys. Jour., vol. XLII, 92 (1915); Mt. Wilson Contr., No. 100.

———. Effective wave-lengths of absolutely faint stars. Astrophys. Jour., vol. XLII, 111 (1915); Mt. Wilson Contr., No. 101.

HESSELBERG, TH. Ueber die Beziehung zwischen Luftdruck und Wind im nichtstationären Fall. Veröff. des Geoph. Inst. der Universität Leipzig, II Serie, H. 7, 173–206.

———. Ueber eine Beziehung zwischen Druckgradient, Wind und Gradientenänderung. Veröff. des Geoph. Inst. der Universität Leipzig, II Serie, H. 8, 207–216.

———. Ueber oszillatorische Bewegungen der Luft. Ann. d. Hydr. u. Mar. Met., 311–317 (1915).

———, and A. FRIEDMANN. Die Grössenordnung der meteorologischen Elemente und ihrer räumlichen und zeitlichen Ableitungen. Veröff. des Geoph. Inst. der Universität Leipzig, II Serie, H. 6, 147–174.

———, and H. U. SVERDRUP. Die Reibung in der Atmosphäre. Veröff. des Geoph. Inst. der Universität Leipzig, II Serie, H. 10, 241–310.

HEWLETT, C. W. Investigation of certain causes responsible for uncertainty in the measurement of atmospheric conductivity by the Gerdien conductivity apparatus. Terr. Mag., vol. 19, No. 4, 219–233 (Dec. 1914). Washington.

HIGGINS, HAROLD L., and JAMES H. MEANS. The effect of certain drugs on the respiration and gaseous metabolism in normal human subjects. Jour. Pharmacol. and Exp. Therapeutics, vol. VII, 1 (1915).

HOLMES, A. See JONES, HARRY C.

HORRAX, GILBERT. A study of the afferent fibers of the body wall and of the hind-legs to the cerebellum of the dog by the method of degeneration. Anat. Rec., vol. IX, 307–321 (1915).

HOSTETTER, J. C. See DAY, ARTHUR L.
———. See SOSMAN, R. B.
HOWE, HENRY M. Hardening with and without martensitization. Trans. Faraday Soc., vol. x, parts 2 and 3, 265 (May 1915).
———, and ARTHUR G. LEVY. Are the deformation lines in manganese steel twins or slip bands? Bull. Amer. Inst. Mining Eng., No. 99, 587 (Mar. 1915).
HOWES, H. L. See NICHOLS, EDWARD L.
HUTCHINSON, J. F. See JONES, HARRY C.
JOHNSTON, JOHN. The solubility-product constant of calcium and magnesium carbonates. Jour. Amer. Chem. Soc., vol. XXXVII, 2001–2020 (1915).
———. Pressure as a factor in the formation of rocks and minerals. Jour. Geol., vol. 23, 730–747 (1915).
———. Druck als ein Faktor der Mineral- und Gesteinsbildung. Neues Jahr. Min. Geol., vol. II, 89–108, 1915.
JONES, HARRY C. Absorptionsspektra und die Solvattheorie der Lösungen. Zeit. für Elektrochemie, Nos. 18, 19 (1914).
———. The electrical nature of matter and radioactivity. 3d ed. (1915). New York.
———. Elements of physical chemistry. 5th ed. (1915). New York.
———, and P. B. DAVIS. The viscosities of binary mixtures of the associated liquids, water, formic acid, and acetic acid. Jour. Amer. Chem. Soc., vol. XXXVII, 1194–1198 (May 1915).
———, M. G. PAULUS, and J. F. HUTCHINSON. Radiometric measurements of the ionisation constants of indicators. II. Jour. Amer. Chem. Soc., vol. XXXVII, 1694–1704 (July 1915).
———, E. J. SHAEFFER, and M. G. PAULUS. Die Aenderung der Absorption des Lichtes durch Wasser infolge der gegenwart stark hydrierter Salze, gemessen mit Hilfe des Radiomikrometers. Physikalische Zeitschrift, 447 (1914).
. . Radiometric measurements of the ionisation constants of indicators. Jour. Amer. Chem. Soc., vol. XXXVII, 776–807 (Apr. 1915).
———, E. P. WIGHTMAN, and J. B. WIESEL. A preliminary study of the conductivity of certain organic acids in absolute ethyl alcohol at 15°, 25°, and 35°. Jour. Amer. Chem. Soc., vol. XXXVI, 2243–2259 (Nov. 1914).
———, ———, P. B. DAVIS, and A. HOLMES. Conductibilities et viscosités des solutions d'iodure de potassium, et d'iodure de sodium dans des mélanges d'alcool ethylique et d'eau. Jour. Chim. Phys., vol. XII, 385 (1914).
JOSLIN, ELLIOTT P. Carbohydrate utilization in diabetes based upon studies of the respiration, urine, and blood. The Harvey Lectures delivered under the auspices of the Harvey Society of New York, 1914–1915; also Arch. Internal Med., vol. 16, 693 (1915).
———. Present-day treatment and prognosis in diabetes mellitus. Amer. Jour. Med. Sci., vol. CL, 485 (1915).
KAPTEYN, J. C. On a device for avoiding systematic error depending on magnitude in the measurement of stellar photographs. Astrophys. Jour., vol. XLI, 77 (1915).
———, and WALTER S. ADAMS. The relations between the proper motions and the radial velocities of the stars of the spectral types F, G, K, and M. Proc. Nat. Acad. Sci., vol. 1, 14 (1915); Mt. Wilson Communications, No. 1.
KING, ARTHUR S. Some features of the spectra of iron and chromium in the vacuum arc. Pubs. A. S. P., vol. 26, 206 (1914).
———. The leading characteristics of the electric furnace spectra of vanadium and chromium. Presented at 74th meeting, Amer. Phys. Soc.; Phys. Rev., ser. 2, vol. 5, 79 (1915).
———. Electric furnace evidence on the relation of spectrum lines having constant differences in wave-number. Presented at 77th meeting, Amer. Phys. Soc.; Phys. Rev., ser. 2, vol. 6, 52 (1915).
———. The variation with temperature of the electric furnace spectra of vanadium and chromium. Astrophys. Jour., vol. XLI, 86 (1915); Mt. Wilson Contr., No. 94.
———. The tube-arc spectrum of iron and a comparison with dissymmetries in spark spectra. Astrophys. Jour., vol. XLI, 373 (1915); Mt. Wilson Contr., No. 103.
———. Unsymmetrical lines in tube-arc and spark spectra as an evidence of a displacing action in these sources. Proc. Nat. Acad. Sci., vol. 1, 371 (1915); Mt. Wilson Communications, No. 9.
———. The variation with temperature of the electric furnace spectra of cobalt and nickel. Astrophys. Jour., vol. XLII (1915); Mt. Wilson Contr., No. 108.
———. A summary of the leading features of electric furnace spectra. Read at joint meeting, Amer. Assn. Adv. Sci. and affiliated societies (1915).
———. The spectrum of the tube-arc and a comparison with line dissymmetries in spark spectra. Read at joint meeting, Amer. Assn. Adv. Sci. and affiliated societies (1915).
LAWRENCE, J. V. See HARRIS, J. A.
LEAVENWORTH, CHARLES S. See OSBORNE, THOMAS B.
LELAND, W. G., and E. C. BURNETT, editors. Letters from Lafayette to Luzerne, 1780–1782. Amer. Hist. Rev., vol. XX, 341–376, 577–612.
LEVY, ARTHUR G. See HOWE, HENRY M.

LEWIS, E. P. The ultra-violet band of ammonia. Astrophys. Jour., vol. XL, 154–155 (July 1914).

———. The continuous spectra of gases. Science, n. s., vol. XLI, 947–948 (June 25, 1915); Nature, vol. 95, 394–395 (June 10, 1915).

———. The effect of self-induction on the nitrogen bands. Astrophys. Jour., vol. XL, 148–152 (July 1914).

———. The origin of the bands in the spectrum of active nitrogen. Philos. Mag., vol. 25, 826–832 (June 1913).

LEWIS, MARGARET REED. Rhythmical contractions of the skeletal muscle observed in tissue culture. Amer. Jour. Physiol., vol. XXXVIII, 153–161 (1915).

———, and WARREN HARMON LEWIS. Mitochondria (and other cytoplasmic structures) in tissue cultures. Amer. Jour. Anat., vol. XVII, 339–401 (1915).

———, ———. Mitochondria in tissue culture. Science, n. s., vol. XXXIX, 330–333 (1914).

LEWIS, WARREN HARMON. See LEWIS, MARGARET REED.

LIVINGSTON, B. E. Atmometry and the porous cup atmometer. Plant World, vol. 18, 21–30, 51–74, 95–111, 143–149 (1915).

———. Atmospheric influence on evaporation and its direct measurement. Missouri Weather Rev., 43, 126–131 (1915).

———. A modification of the Bellani porous plate atmometer. Science, n. s., vol. XLI, 872–874 (1915).

LONG, E. R. Chemical changes accompanying desiccation and partial starvation. Physiol. Researches, vol 1, No. 7, 298–315 (1915).

———. Growth and colloid hydratation in cacti. Bot. Gaz., vol. LIX, 491–497 (1915).

———. Acid accumulation and destruction in large succulents. Plant World, vol. XVIII, 261–272 (1915).

LUCKEY, GEORGE P. See HALE, GEORGE E.

MACDOUGAL, D. T. The experimental modification of germ-plasm. Ann. Mo. Botanic Garden, vol. II, 253–274 (1915).

———. The effect of potassium iodide, methylene blue, and other substances applied to the embryo-sacs of seed-plants. Proc. Soc. Exper. Biol. and Med., 61st meeting, vol. XII, 1–3 (1914).

———. Light and the rate of growth in plants. Science, n. s., vol. XLI, 467 (1915).

———. The end results of the desiccation and starvation of succulent plants. Physiol. Researches, vol. I, No. 7, 289–292 (1915).

———. The Salton Sea. Amer. Jour. Sci., vol. 39, 231–250 (1915).

———. The general course of depletion in starving succulents. Physiol. Researches, vol. I, No. 7, 292–298 (1915).

, and G. SYKES. The travertine record of Blake Sea. Science, W. S., vol. XLI, 133 (1915).

MACDOWELL, E. C. Bristle inheritance in *Drosophila*. I: Extra bristles. Jour. Exper. Zool., vol. 19, 61–98 (July 5, 1915).

MALL, F. P. On the cause of tubal pregnancy and on the fate of the enclosed ovum. Surg., Gynecol. and Obstet., vol. XXI (1915).

———. Scope and organisation of the Department of Embryology. Scope and Organization of the Carnegie Institution of Washington (printed privately) (1914).

MARTIN, W. B. Neutral stains as applied to the granule of the pancreatic islet cells. Anat. Rec., vol. IX, 475–481 (1915).

MAYER, ALFRED G. History of Tahiti, Fiji, Papua, etc. Pop. Sci. Mon. (1915).

———. The nature of nerve-conduction in *Cassiopea*. Proc. Nat. Acad. Sci., vol. 1, 270–274 (1915).

———. Ecology of the Murray Island coral reef. Proc. Nat. Acad. Sci., vol. 1, 211–214 (1915).

MEANS, JAMES H. See HIGGINS, HAROLD L.

MENDEL, LAFAYETTE B. Nutrition and growth. Jour. Amer. Med. Assn., vol. LXIV, 1539–1547 (May 8, 1915).

———. See OSBORNE, THOMAS B.

MERWIN, H. E. Covellite: A singular case of chromatic reflection. Jour. Wash. Acad. Sci., vol. 5, 341–344 (1915).

———. Die thermale Entwässerung des Stilbit und Thaumasit; die Hydrate von Magnesium- und Kupfersulfat. Z. Kryst., Bd. 55, 113–114 (1915).

———. See POSNJAK, EUGEN.

———. See SOSMAN, R. B.

See WASHINGTON, H. S.

METZ, B. S. See METZ, CHARLES W.

METZ, CHARLES W. An apterous *Drosophila* and its genetic behavior. Amer. Nat., vol. XLVIII 675–692 (Nov. 1914).

———, and B. S. METZ. Mutations in two species of *Drosophila*. Amer. Nat., vol. XLIX, 187–189 (Nov. 1915).

MOULTON, F. R. On the stability of direct and retrograde satellite orbits. Monthly Notices Royal Astronom. Soc., vol. 75, 40–57.

MOULTON, F. R. George Ellery Hale. Technical World, vol. 22.
———, ———. Solution of an infinite system of differential equations of the analytic type. Proc. Nat. Acad. Sci., vol. 1, 350–354 (1915).
NICHOLS, EDWARD L., and H. L. HOWES. The fluorescence of kunsite. Phys. Rev., vol. IV, 18 (July 1914).
———, ———. The polarized fluorescence of ammonium uranyl chloride. Proc. Nat. Acad. Sci., vol. 1, 444 (Aug. 1915).
OSBORNE, THOMAS B., and LAFAYETTE B. MENDEL. The influence of beef fat on growth. Proc. Soc. Biol. and Med., vol. XII, 92 (Jan. 1915).
———, ———. The comparative nutritive value of certain proteins in growth, and the problem of the protein minimum. Jour. Biol. Chem., vol. XX, 351–378 (Mar. 1915).
———, ———. Further observations of the influence of natural fats upon growth. Jour. Biol. Chem., vol. XX, 379–389 (Mar. 1915).
———, ———. Protein minima for maintenance. Jour. Biol. Chem., vol. XXII, 241–258 (Sept. 1915).
———, DONALD D. VAN SLYKE, CHARLES S. LEAVENWORTH, and MIRIAM VINOGRAD. Some products of hydrolysis of gliadin, lactalbumin, and the protein of the rice kernel. Jour. Biol. Chem., vol. XXII, 259–280 (Sept. 1915).
———, and ALFRED J. WAKEMAN. Does butter-fat contain nitrogen and phosphorus? Jour. Biol. Chem., vol. XXI, 91–94 (May 1915).
———, ———. Some new constituents of milk. First paper: The phosphatides of milk. Jour. Biol. Chem. (in press, 1915).
———. See WELLS, H. GIDEON.
PAULUS, M. G. See JONES, HARRY C.
PEASE, FRANCIS G. The radial velocity of the nebula N. G. C. 1068. Pubs. A. S. P., vol. 27, 133 (1915).
———. Radial velocity of the Andromeda nebula. Pubs. A. S P., vol. 27, 134 (1915).
———. See ADAMS, WALTER S.
PETERS, W. J. See BAUER, L. A.
POSNJAK, EUGEN, and E. T. ALLEN (thermal and chemical study), H. E. MERWIN (microscopic study). The sulphides of copper. Econ. Geol., vol. 10, 491–535.
———, ——— (thermochemische Untersuchungen), H. E. MERWIN (mikroskopische Untersuchungen). Die Kupfersulfiden. Z. anorg. Chem. (in press).
PRATT, L. G. See DAVIS, P. B.
RANKIN, G. A. The constituents of portland cement clinker. Jour. Ind. Eng. Chem., vol. 7, 466–474 (1915); Concrete-Cement Age, vol. 6, 55–63 (1915).
RAYMOND, H. Preferential motion according to type. Astron. Jour., No. 676, No. 4, vol. XXIX (1915).
RICHARDS, THEODORE W. Further remarks concerning the chemical significance of crystalline form. Jour. Amer. Chem. Soc., vol. XXXVI, 1686 (Aug. 1914).
———. An advantageous form of still for the exact measurement of boiling point during fractional distillation. Jour. Amer. Chem. Soc., vol. XXXVI, 1787 (Aug. 1914).
———. The freezing point of benzene as a fixed point in thermometry. Jour. Amer. Chem. Soc., vol. XXXVI, 1825 (Sept. 1914).
———. The present aspect of the hypothesis of compressible atoms. Jour. Amer. Chem. Soc., vol. XXXVI, 2417–2439 (Dec. 1914).
———. The inclusion of electrolyte by the deposit in the silver voltameter. Jour. Amer. Chem. Soc., vol. XXXVII, 7 (Jan. 1915).
———. A new thermochemical method for subdividing accurately a given interval on the thermometer scale. Jour. Amer. Chem. Soc., vol. XXXVII, 81 (Jan. 1915).
———. The molecular weight of sodium carbonate and the atomic weight of carbon referred to silver and bromine. Jour. Amer. Chem. Soc., vol. XXXVII, 95 (Jan. 1915).
———. The molecular weight of sodium sulfate and the atomic weight of sulfur. Jour. Amer. Chem. Soc., vol. XXXVII, 108 (Jan. 1915).
———. Compressibilities of mercury, copper, lead, molybdenum, tantalum, tungsten, and silver bromide. Jour. Amer. Chem. Soc., vol. XXXVII, 470 (Mar. 1915).
———. The heats of combustion of aromatic hydrocarbons and hexamethylene. Jour. Amer. Chem. Soc., vol. XXXVII, 993 (May 1915).
———. Concerning the compressibilities of the elements, and their relations to other properties. Proc. Nat. Acad. Sci., vol. 1, 411–415 (June 1915); Jour. Amer. Chem. Soc., vol. XXXVII, 1643–1656 (July 1915).
———. A synthermal regulator: an automatic device for maintaining equality of temperature in an adiabatic calorimeter. Jour. Amer. Chem. Soc., vol. XXXVII, —— (July 1915).
———, and F. A. ANDEREGG. The complications at the anode in the silver coulometer (voltameter). Jour. Amer. Chem. Soc., vol. XXXVII, 675–693 (Apr. 1915).
———, and FREDERICK BARRY. The heats of combustion of aromatic hydrocarbons and hexamethylene. Jour. Amer. Chem. Soc., vol. XXXVII, 993–1020 (May 1915).

Richards, Theodore W., and Leslie B. Coombs. The surface tensions of water, methyl, ethyl and isobutyl alcohols, ethyl butyrate, benzene, and toluene. Proc. Nat. Acad. Sci., vol. 1, 404–407 (June 1915); Jour. Amer. Chem. Soc., vol. xxxvii, 1656–1676 (July 1915).

Roth, Paul. See Benedict, Francis G.

Schlesinger, M. D. See Sherman, H. C.

Schulemann, Werner. See Evans, Herbert M.

Scott, Katherine J. The relation of mitochondria to the granules of vital azo dyes. Science, n. s., vol. xli, 834–835 (1915).

Seares, Frederick H. Photographic and photovisual magnitudes of stars near the North Pole. Astrophys. Jour., vol. xli, 206 (1915); Mt. Wilson Contr., No. 97.

———. A comparison of the Harvard and Mount Wilson scales of photographic magnitude. Astrophys. Jour., vol. xli, 259–290 (1915); Mt. Wilson Contr., No. 98.

———. Color-indices in the cluster N. G. C. 1647. Astrophys. Jour., vol. xlii, 120 (1915); Mt. Wilson Contr., No. 102.

———. Absolute scales of photographic and photovisual magnitude. Proc. Nat. Acad. Sci., vol. 1, 309 (1915); Mt. Wilson Communications, No. 8.

———. A notation for use in the discussion of star colors. Proc. Nat. Acad. Sci., vol. 1, 481–482 (Sept. 1915); Mt. Wilson Communications, No. 16.

———. Photographic magnitudes of stars in the Selected Areas. Presented at 18th meeting, Amer. Astron. Soc.

———, and Harlow Shapley. Distribution of colors among the stars of N. G. C. 1647 and M. 67. Proc. Nat. Acad. Sci., vol. 1, 483–486 (Sept. 1915); Mt. Wilson Communications, No. 17.

Shaeffer, E. J. See Jones, Harry C.

Shapley, Harlow. Miscellaneous notes on variable stars. Astrophys. Jour., vol. xli, 291–306 (1915); Mt. Wilson Contr., No. 99.

———. Note on the densities of second-type stars. Astrophys. Jour., vol. xlii (1915); Mt. Wilson Contr., No. 107.

———. Second-type stars of low mean density. Proc. Nat. Acad. Sci., vol. 1, 459 (1915); Mt. Wilson Communications, No. 15.

———. Color indices in the system of T W Andromedæ. Pubs. A. S. P., vol. 26, 258 (1914).

———. Note on the color of the faint stars in the Orion nebula. Pubs. A. S. P., vol. 27, 40 (1915).

———. Four new variable stars in the Hercules cluster. Pubs. A. S. P., vol. 27, 134 (1915).

———. Note on the periods of close binaries. Pubs. A. S. P., vol. 27, 135 (1915).

———. Magnitudes and colors of stars in the Hercules cluster. Read at 18th meeting, Amer. Astron. Soc.

———. Review of Przybyllok, Polhohen-Schwankungen. Astrophys Jour, vol. xli, 328 (1915).

———, and Henry Norris Russell On the distribution of eclipsing variable stars in space. Astrophys. Jour., vol xl, 417 (1914).

———, and Martha Betz Shapley. The light curve of XX Cygni as a contribution to the study of cepheid variation, Proc. Nat. Acad. Sci., vol. 1, 452 (1915); Mt. Wilson Communications, No. 14.

———. See Seares, Frederick H.

Shapley, Martha Betz. See Shapley, Harlow.

Shepherd, E. S. See Day, Arthur L.

Sherman, H. C., and M. D. Schlesinger. Further experiments upon the purification of malt amylase. Jour. Amer. Chem. Soc., vol. xxxvii, 643–648 (Mar. 1915).

———, ———. A comparison of certain properties of pancreatic and malt amylase preparations. Jour. Amer. Chem. Soc., vol. xxxvii, 1305–1319 (May 1915).

———, and A. W. Thomas. The influence of certain acids and salts upon the activity of malt amylase. Jour. Amer. Chem. Soc., vol. xxxvii, 623–643 (Mar. 1915).

Shipley, P. G. The mitochondrial substance in the erythrocytes of the embryo pig. Folia Hæmatol., vol. xix (1915).

Shive, J. W. An improved non-absorbing porous cup atmometer. Plant World, vol. 18, 7–10, (1915).

Shreve, Edith B. Air investigation of the causes of autonomic movements in succulent plants. I. Plant World, vol. xviii, 297–312. II. 331–343.

Shreve, Forrest. The direct effects of rainfall on hygrophilous vegetation. Jour. Ecol., vol. ii, 82–98, 1 pl. (June 1914).

Shull, G. H. Duplicate genes for capsule-form in *Bursa bursa-pastoris*. Zeit. f. indukt. Abstammungs u. Vererbungslehre, Bd. xii, H. 2, 97–149 (1914).

———. Genetic definitions in the New Standard Dictionary. Amer. Nat., vol. xlix, 52–59 (Jan. 1915).

Smith, H. Monmouth. See Benedict, Francis G.

Sommer, H. Oskar. The structure of Le Livre D'Artus and its function in the evolution of the Arthurian prose-romances. 8vo (1914). London.

SOSMAN, R. B., and J. C. HOSTETTER. A vacuum furnace for the measurement of small dissociation pressures. Jour. Wash. Acad. Sci., vol. 5, 277–285 (1915).

———, ———. Ein Vakuumofen für die Messung kleiner Dissoziationsdrucken. Z. Elektrochemie (in press).

———, ———. The reduction of iron oxides by platinum, with a note on the magnetic susceptibility of iron-bearing platinum. Jour. Wash. Acad. Sci., vol. 5, 293–303 (1915).

———, ———, and H. E. MERWIN. The dissociation of calcium carbonate below 500° C. Jour. Wash. Acad. Sci., vol. 5, 563–569 (1915).

See DAY, ARTHUR L.

STEWART, OLUS J. See BAXTER, GREGORY P.

ST. JOHN, CHARLES E. Anomalous dispersion in the sun in the light of observations. Astrophys. Jour., vol. XLI, 28 (1915); Mt. Wilson Contr., No. 93.

———. Critique of the hypothesis of anomalous dispersion in certain solar phenomena. Proc. Nat. Acad. Sci., vol. 1, 21 (1915); Mt. Wilson Communications, No. 2.

———, WALTER S. ADAMS, and LOUISE WARE. Recent observations of the rotation of the sun. Read at 18th meeting, Amer. Astron. Soc.

———, and HAROLD D. BABCOCK. Variability of spectrum lines in the iron arc. Proc. Nat. Acad. Sci., vol. 1, 131 (1915); Mt. Wilson Communications, No. 5.

———, ———. On the pole effect in the iron arc. Proc. Nat. Acad. Sci., vol. 1, 295 (1915); Mt. Wilson Communications, No. 7.

———, ———. A study of the pole effect in the iron arc. Astrophys. Jour., vol. XLII (1915); Mt. Wilson Contr., No. 106.

Pole effect in the arc and its relation to other investigations. Read at joint meeting of Amer. Assn. Adv. Sci. and affiliated societies (1915).

STREETER, G. L. Experiments on the amphibian ear vesicle. Anat. Rec., vol. IX (1915).

———. The development of the venous sinuses of the dura mater in the human embryo. Amer. Jour. Anat., vol. 18, 145–178 (1915).

SUTTON, ALAN C. On the development of the neuro-muscular spindle in the extrinsic eye muscles of the pig. Amer. Jour. Anat., vol. 18, 117–144 (1915).

SVERDRUP, H. U. Temperaturinversionen in etwa 4000 m Höhe in der Nähe der Alpen. Met. Zeitsch., 283–284 (1915).

———. See HESSELBERG, TH.

SWANN, W. F. G. On certain matters relating to the theory of atmospheric-electric measurements. Terr. Mag., vol. 19, No. 4, 205–218 (Dec. 1914). Washington.

———. The atmospheric-electric observations on the third cruise of the *Carnegie*, 1914. Report and discussion. Terr. Mag., vol. 20, 13–48 (Mar. 1915). Washington.

The origin and maintenance of the Earth's charge. Part 1. Terr. Mag., vol. 20, 105–126 (Sept. 1915). Washington.

SYKES, G. The mythical straits of Anian. Bull. Amer. Geog. Soc., vol. XLVII, 161–172, 10 maps (March 1915).

———. How California got its name. Out West, Los Angeles, Cal. (June 1915).

———. The isles of California Bull. Amer. Geograph. Soc. New York, vol. XLVII, 729–761 (Oct. 1915)

———. The reclamation of a desert. Geograph. Jour., London (Dec. 1915). In press.

See MACDOUGAL, D. T.

TALBOT, FRITZ B. The energy metabolism of an infant with congenital absence of the cerebral hemispheres. Arch. Pediatrics, vol. XXXII, 452 (1915).

THOMAS, A. W. See SHERMAN, H. C.

THORVALDSON, T. See BAXTER, GREGORY P.

VAN MAANEN, A. Photographic determination of stellar parallaxes with the 60-inch reflector. Proc. Nat. Acad. Sci., vol. 1, 187 (1915); Mt. Wilson Communications, No. 6; read at 18th meeting, Amer. Astron. Soc.

———. List of stars with proper motion exceeding 0″.50 annually. Astrophys. Jour., vol. XLI, 187 (1915); Mt. Wilson Contr., No. 96.

VAN SLYKE, DONALD D. See OSBORNE, THOMAS B.

VAUGHAN, THOMAS WAYLAND. Coral reefs and reef corals of the southeastern United States; their geologic history and significance. Bull. Geol. Soc. Amer., vol. 26, 58–60; Science, n. s., vol. XLI, 508–509 (1915).

———. Present status of the geologic correlation of the geologic formations in the West Indies. Jour. Wash. Acad. Sci., vol. 5, 489–490 (1915).

———. Memorandum on the geology of the ground waters of the island of Antigua, B. W. I. Reprinted from West Indian Bulletin, vol. XIV, No. 4 (1915).

VINOGRAD, MIRIAM. See OSBORNE, THOMAS B.

WAKEMAN, ALFRED J. See OSBORNE, THOMAS B.

WALLIS, W. F. See FLEMING, J. A.

WARE, LOUISE. See ST. JOHN, CHARLES E.

WASHINGTON, H. S. The calculation of calcium orthosilicate in the norm of igneous rocks. Jour. Wash. Acad. Sci., vol. 5, 345–350 (1915).

WASHINGTON, H. S. Contributions to Sardinian petrography: I. The rocks of Monte Ferru. Amer. Jour. Sci. (4), vol. xxxix, 513–529 (1915).

——— and ARTHUR L. DAY. Present condition of the volcanoes of Southern Italy. Bull. Geol. Soc. Amer., vol. 26, 375–388 (1915).

———, and H. E. MERWIN. Nephelite crystals from Monte Ferru, Sardinia. Jour. Wash. Acad. Sci., vol. 5, 389–391 (1915).

WELLS, H. GIDEON, and THOMAS B. OSBORNE. The anaphylactic reaction with so-called "proteoses" of various seeds. The biological reactions of the vegetable proteins, VI. Jour. Infectious Diseases (1915).

WHITE, WALTER P. Mechanical strain and thermoelectric power. Phys. Rev., vol. 6, 234–236 (1915).

WIESEL, J. B. See JONES, HARRY C.

WIGHTMAN, E. P. See JONES, HARRY C.

WOODWARD, R. S. Note on the orbits of freely falling bodies. Science, n. s., vol. XLI, 492–495 (Apr. 2, 1915).

WRIGHT, FRED. E. Obsidian from Hrafntinnuhryggur, Iceland: Its lithophysæ and surface markings. Bull. Geol. Soc. Amer., vol. 26, 255–286 (1915).

———. Der optische Charakter der schwachen, mit starken Objektiven zwischen gekreuzten Nicols beobachten Interferenzfigur. Z. Kryst., Bd. 55, 115–122 (1915).

———. The accurate measurement of the refractive indices of minute crystal grains under the petrographic microscope. Jour. Wash. Acad. Sci., vol. 5, 101–107 (1915).

———. Die Messung der Brechungsexponenten mit dem petrographischen Mikroskop. Z. Kryst. (in press).

WRIGHT, SEWALL. Duplicate genes. Amer. Nat., vol. 48, 638 (1914).

———. The albino series of allelomorphs in guinea-pigs. Amer. Nat., vol. 49, 140–148 (1915).

———. See CASTLE, W. E.

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the year 1914–1915.

During the fiscal year ending October 31, 1915, the Executive Committee held eleven meetings, including joint meetings with the Finance Committee on January 23, 1915, and March 18, 1915. Printed reports of these meetings have been sent to the Trustees of the Institution.

Upon the adjournment of the Board of Trustees on December 11, 1914, the members of the Executive Committee met and organized by the election of Mr. Welch as Chairman for 1915, and by voting that the Assistant Secretary of the Institution act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1914–1915, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits a report and an outline of suggested appropriations for the year 1916. The Executive Committee hereby approves the report and the recommendations of the President as the report and recommendations of the Committee.

The Board of Trustees at its meeting of December 11, 1914, appointed Messrs. Heins and Whelen of Philadelphia to audit the accounts of the Institution for the fiscal year ending October 31, 1915. This firm was dissolved shortly afterward, however, and the Executive Committee at its meeting of January 23, 1915, appointed the firm of Messrs. Lybrand, Ross Brothers, and Montgomery, of Philadelphia, as auditors for the past year. The report of this company is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a balance sheet, showing the condition of the assets and liabilities of the Institution on October 31, 1915, together with statements of receipts and disbursements for the fiscal year and of aggregate receipts and disbursements since the organization of the Institution on January 28, 1902.

Mr. Henry L. Higginson submitted his resignation as a member of the Finance Committee and it was accepted with regret by the Execu-

tive Committee at its meeting of January 23, 1915. Whereupon, Mr. Henry S. Pritchett was appointed by the Executive Committee, in accordance with the provisions of Section 9 of Article V of the By-Laws, to fill the vacancy thus created in the Finance Committee until the next meeting of the Board of Trustees.

A vacancy in the Board of Trustees, occasioned by the death of Mr. William N. Frew, calls for action at the coming meeting of the Board of Trustees. In accordance with the further provision of the By-Laws, names to fill such vacancy have been requested and submitted to members of the Board.

The terms of office of the following members of the Board of Trustees will expire at the coming annual meeting: Mr. Root, as Chairman of the Board; Mr. Walcott, as Vice-Chairman; Mr. Dodge, as Secretary; Messrs. Parsons, Pritchett, and Walcott, as members of the Executive Committee; Messrs. Dodge, Pritchett, and Wickersham, as members of the Finance Committee, and Messrs. Brookings, Hutchinson, and Wickersham, as members of the Auditing Committee.

William H. Welch, *Chairman.*
Cleveland H. Dodge.
Wm. Barclay Parsons.
Henry S. Pritchett.
Elihu Root.
Charles D. Walcott.
Henry White.
Robert S. Woodward.

November 22, 1915.

Balance Sheet, October 31, 1915.

ASSETS.

INVESTMENTS:		
Securities (page 48)	$23,429,156.40	
Cash (uninvested principal) (page 46)	209,924.15	
		$23,639,080 55
PROPERTY ACCOUNT:		
Real estate, equipment, and publications (page 49)		2,567,145 28
CURRENT ASSETS:		
Cash (page 46)	218,031.23	
Stamps and petty cash	300.00	
Income receivable (1915)	128,775.30	
		347,106.53
		26,553,332 36

LIABILITIES.

ENDOWMENT	$22,120,000.00	
COLBURN FUND	4,950.00	
RESERVE FUND	1,372,726.47	
INSURANCE FUND	141,404.08	
		$23,639,080.55
INVESTED IN PROPERTY		2,567,145.28
CURRENT LIABILITIES:		
Large grants (page 49)	151,294.38	
Minor grants (page 50)	46,662.08	
Publication (page 51)	86,314.83	
Administration	16,642.06	
		300,913.35
UNAPPROPRIATED FUND		46,193.18
		26,553,332.36

Receipts and Disbursements for the year ending October 31, 1915.

RECEIPTS.

Interest:		
Endowment—		
Bonds	$1,100,375.00	
Bank balance	8,532.25	
		$1,108,907.25
Reserve Fund—		
Bonds	52,805.00	
Bank balance	1,097.66	
		53,902.66
Insurance Fund—		
Bonds	5,363.83	
Bank balance	89.57	
		5,453.40
Colburn Fund		750.00
Sales of Publications:		
Index Medicus	5,010.21	
Year Book	47.60	
Miscellaneous books	5,239.98	
		10,297 79
Refund on Grants:		
Grant No. 936	125.00	
937	650.00	
900	150.00	
916	200.00	
884	17.24	
943	100.00	
942	1,000.00	
1012	1,650.00	
1003	4,000.00	
945	48.74	
1023	10.12	
1011	126.00	
964	128.71	
1009	19.00	
968	76.06	
975	22.00	
		8,322.87
Miscellaneous:		
Refund, shipping	184.46	
paper and printing	1,228.33	
		1,412.79
Redemption of Securities:		
Baltimore & Ohio		26,000.00
		1,215,046.76
Balance October 31, 1914		394,092.38

DISBURSEMENTS.

Investment:		
Securities		$206,203.21
Grants:		
Large	$770,488.58	
Minor	109,569.37	
		880,057.95
Publication		46,698.56
Administration:		
Trustees	3,630 45	
Executive Committee	2,289.60	
Salaries	26,932.00	
Publication—shipping expenses	5,690.18	
Surety, rent, telephone	438.60	
Equipment	199.00	
Stationery	116.35	
Postage, express, etc	537.59	
Printing	3,060.85	
Office supplies and petty expenses	1,373.82	
Building and grounds—		
Supplies and janitor service	2,674.22	
Fuel, light, water	1,281.38	
		48,224.04
		1,181,183.76
Cash in Banks:		
Endowment	1,796.20	
Reserve Fund	201,085.63	
Insurance Fund	6,292.32	
Colburn Fund	750.00	
	209,924.15	
Drawing Accounts	218,031.23	
		427,955.38

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1915.

RECEIPTS.

INTEREST:		
Endowment bonds	$9,883,814.17	
Reserve Fund bonds	131,391.25	
Insurance Fund bonds	12,944.77	
Income and Building Fund bonds	95,629.06	
Deposits in banks	136,883.67	
		$10,260,662.92
COLBURN FUND		750 00
SALES OF PUBLICATIONS:		
Index Medicus	50,709.69	
Year Book	814.66	
Miscellaneous	52,439.68	
		103,964.03
REFUND ON GRANTS		35,266.08
MISCELLANEOUS:		
Organization	1,825.52	
Sale of furniture	87.00	
Postage, express, and travel	56.65	
Printing and paper	5,460.51	
Sale of metal cuts	77.40	
Refund, shipping	671.61	
office	59.43	
insurance	4,717.00	
telephone, light	34.89	
trustees	32.03	
building	68.53	
executive committee	25.00	
bond commission	1,274.37	
		14,389 94
REDEMPTION AND SALE OF BONDS;		
U. S. Steel Corporation	920,000.00	
Northern Pacific-Great Northern	48,000.00	
Northern Pacific	102,750.00	
Atchison, Topeka and Santa Fe	49,500.00	
Lake Shore and Michigan Southern	47,000.00	
Central Pacific	48,250.00	
Baltimore and Ohio	26,000.00	
		1,241,500.00
		11,656,532.97

DISBURSEMENTS.

INVESTMENT:		
Securities	$2,569,271.62	
Administration building and site	309,915.69	
		$2,879,187.31
GRANTS:		
Large	5,853,681.37	
Minor	1,391,603.29	
		7,245,284.66
PUBLICATION		507,399.63
ADMINISTRATION:		
Trustees	32,424.12	
Executive Committee	22,513.53	
Honorariums	17,319.81	
Salaries	354,490.03	
Publication—shipping expenses	26,412.74	
Rent, surety, telephone	30,032.80	
Equipment	13,955.56	
Stationery	12,561.13	
Postage, express	20,421.34	
Printing	*34,751.28	
Office expenses	5,494.34	
Building and grounds—		
Supplies and janitor service	13,511.33	
Fuel, light, water	5,092.93	
Organization (1902)	1,825.52	
Plans and option	5,166.46	
Seal (1903)	555.60	
Miscellaneous	70.23	
		596,598.75
REFUND:		
Publication	20.25	
Index Medicus	86.99	
		107.24
		11,228,577.59
CASH IN BANKS (page 46)		427,955.38
		11,656,532.97

*Including Year Book.

Schedule of Securities.

Par value.	Securities.	Investment value.	Total.
	ENDOWMENT.		
$21,200,000	U. S. Steel Corporation, registered 50-year 5 per cent gold bonds, Series A, B, C, D, E, and F, due Apr. 1, 1951.	$21,200,000	
175,000	Chicago, Milwaukee & Puget Sound Rwy. Co., first mortgage 4 per cent gold bonds, due Jan. 1, 1949	159,268.00	
13,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent gold bonds, due May 1, 1989	12,935.00	
325,000	Lehigh & Lake Erie R. R. Co., first mortgage 4½ per cent 50-year gold bonds, due Mar. 1, 1957	331,568.30	
237,000	New York City 4½ per cent registered bonds, due Mar. 1, 1963	253,557.50	
150,000	South & North Alabama R. R. Co., consolidated mortgage 5 per cent bonds, due Aug. 1, 1936	160,875.00	
			$22,118,203.80
	COLBURN FUND.		
42,000	Pittsburgh, Shawmut & Northern R. R., first mortgage 4 per cent bonds, due Feb. 1, 1952		4,200.00
	INSURANCE FUND.		
28,000	American Telephone & Telegraph Co., 4½ per cent convertible bonds	28,978.00	
50,000	Atchison, Topeka & Santa Fe Rwy. Co., general mortgage, 100-year, 4 per cent registered gold bonds, due 1995.	50,056.25	
25,000	Bell Telephone Co. of Canada, debenture 5 per cent bonds, due Apr. 1, 1925	24,760.00	
1,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent gold bonds, due May 1, 1989	995.00	
6,000	Illinois Central R. R. Co., refunding mortgage 4 per cent bonds, due Nov. 1, 1955	5,227.50	
24,000	Pennsylvania R. R. Co., consolidated mortgage 4½ per cent bonds, due Aug. 1, 1960	25,095.01	
			135,111.76
	RESERVE FUND.		
50,000	American Telephone & Telegraph Co., collateral trust 4 per cent bonds, due 1929	45,500.00	
96,000	American Telephone & Telegraph Co., 4½ per cent convertible bonds	99,456.25	
50,000	Central Pacific Rwy. Co., first refunding mortgage 4 per cent registered gold bonds, due 1949	48,250.00	
15,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent gold bonds, due May 1, 1989	14,925.00	
10,000	Cleveland Telephone & Telegraph Co., 2-year 5 per cent notes, due May 15, 1916	9,937.50	
2,000	Cumberland Telephone & Telegraph Co., 2-year 5 per cent notes, due Apr. 1, 1916	1,987.50	
15,000	Great Northern Rwy. Co., first and refunding mortgage 4½ per cent bonds, due 1961	15,227.00	
155,000	General Electric, 5 per cent gold debenture bonds	158,213.47	
280,000	Interborough Rapid Transit Co., first refunding mortgage 5 per cent bonds, due 1966	276,701.00	
25,000	Iowa Telephone Co., 2-year 5 per cent notes, due Apr. 1, 1916	24,843.75	
50,000	Lake Shore & Michigan Southern Rwy. Co., registered 25-year 4 per cent gold bonds, due Sept. 1, 1928	47,000.00	
50,000	Long Island R. R. Co., refunding mortgage 4 per cent bonds, due 1949	48,285.00	
50,000	City of New York 6 per cent coupon bearer revenue bonds, due Sept. 1, 1916	50,875.00	
13,000	Nebraska Telephone Co., 2-year 5 per cent notes, due Apr. 15, 1916	12,918.75	
50,000	New York, Westchester & Boston Rwy. Co., first mortgage 4½ per cent bonds, due 1946	49,187.50	
50,000	Northern Pacific-Great Northern (Chicago, Burlington & Quincy collateral), joint 4 per cent bonds, due 1921	49,037.50	
50,000	Oregon-Washington R. R. & Navigation Co., first and refunding 4 per cent mortgage bonds, due 1961	46,375.00	
20,000	Pennsylvania R. R. Co., general mortgage 4½ per cent bonds, due June 1, 1965	19,625.00	
101,000	Pennsylvania R. R. Co., consolidated mortgage 4½ per cent bonds, due Aug. 1, 1960	105,608.12	
50,000	United Fruit Co., 4-year 5 per cent gold coupon bearer notes, due May 1, 1918	47,687.50	
			1,171,640.84
23,458,000			23,429,156.40

Schedule of Real Estate, Equipment, and Publications.

ADMINISTRATION:		
Building, site, and equipment		$332,179.61
PUBLICATIONS:		
Stock on hand (Oct. 31, 1915)	$236,594.35	
Outstanding accounts (Oct. 31, 1915)	1,981.05	
		238,575.40
DEPARTMENT OF BOTANICAL RESEARCH (SEPT. 30, 1915):		
Buildings, office, and operating	49,385.10	
Laboratory equipment	12,063.21	
		61,448.31
DEPARTMENT OF EXPERIMENTAL EVOLUTION (SEPT. 30, 1915):		
Buildings, office, and library	103,149.20	
Laboratory apparatus	7,248.25	
Operating appliances, and grounds	19,897.95	
		130,295.40
GEOPHYSICAL LABORATORY (SEPT. 30, 1915):		
Building, library, and operating appliances	120,524 84	
Laboratory apparatus	75,832 81	
Shop equipment	15,084 66	
		211,442.31
DEPARTMENT OF HISTORICAL RESEARCH (SEPT. 30, 1915):		
Office	2,008.03	
Library	2,930.46	
		4,938.49
DEPARTMENT OF MARINE BIOLOGY (SEPT. 30, 1915):		
Vessels	32,325.40	
Buildings, docks, furniture, and library	11,651 96	
Apparatus and instruments	4,981 94	
		48,959.30
DEPARTMENT OF MERIDIAN ASTROMETRY (SEPT. 30, 1915):		
Apparatus and instruments	2,394.34	
Operating	1,277 62	
		3,671.96
NUTRITION LABORATORY (SEPT. 30, 1915):		
Building, office, and shop	117,200.15	
Laboratory apparatus	20,827.26	
		138,027.41
MOUNT WILSON SOLAR OBSERVATORY (AUG. 31, 1915):		
Buildings, grounds, road, and telephone line	196,193.06	
Shop equipment	37,129 26	
Instruments	394,460.17	
Furniture and operating appliances	84,483.28	
Hooker 100-inch reflector	371,219.66	
		1,083,485.43
DEPARTMENT OF TERRESTRIAL MAGNETISM (SEPT. 30, 1915):		
Building, site, and office	131,616.33	
Vessel and survey equipment	129,417.12	
Instruments, laboratory, and shop equipment	53,088.21	
		314,121.66
		2,567,145.28

Balances Due Large Grants.

Department of Botanical Research	$3,865.00
Department of Economics and Sociology	30,350.59
Department of Experimental Evolution	6,221.11
Geophysical Laboratory	26,683.88
Department of Historical Research	6,700.00
Department of Marine Biology	4,335.84
Department of Meridian Astrometry	4,027.18
Nutrition Laboratory	14,242.59
Division of Publications	2,088.33
Solar Observatory	23,508.81
Department of Terrestrial Magnetism	15,464.52
Department of Embryology	13,806.53
	151,294.38

Balances Due Minor Grants.

ASTRONOMY:	
Kapteyn, J. C	$333.40
ARCHEOLOGY:	
Van Deman, E. B	1,200.00
Morley, S. G	694.76
BIBLIOGRAPHY:	
Index Medicus	7,293.85
BIOLOGY:	
Dutra, J	100.00
Jackson, R. T	282.50
Morgan, T. H	1,925.05
Vaughan, T. W	362.80
Do	35.10
BOTANY:	
Britton and Rose	1,020.00
Clements, F. E	133.36
CHEMISTRY:	
Jones, H. C	1,100.02
Morse, H. N	666.70
Noyes, A. A	333.40
Osborne, T. B., and L. B. Mendel	4,983.43
Sherman, H. C	200.00
Remsen, Ira	1,216.67
GEOLOGY:	
Chamberlin, T. C	3,318 24
Moulton, F. R	458.40
HISTORY:	
Andrews, C. M	500.02
Bandelier, Fanny R	333.40
Osgood, H. L	200.00
Turner, Frederic J	3,600.00
LITERATURE:	
Bergen, Henry	300.00
MATHEMATICS:	
Morley, Frank	600.00
METEOROLOGY:	
Bjerknes, V	450.00
PALEONTOLOGY:	
Case, E. C	250.00
Hay, O. P	1,079.26
Wieland, G. R	592.50
PHILOLOGY:	
Churchill, William	2,083.38
PHYSICS:	
Hayford, J. F	66.72
Nichols, E. L	4,500.00
Nipher, F. E	364.63
PHYSIOLOGY:	
Reichert, E. T	1,500.00
ZOOLOGY:	
Castle, W. E	416.70
EXHIBIT AT PANAMA-PACIFIC INTERNATIONAL EXPOSITION	1,522.61
DEPARTMENT OF TERRESTRIAL MAGNETISM (INS.)	200.00
UNALLOTTED:	
Minor grants	2,445.18
	46,662.08

Balances Due Publication Account.

American Ethnological Society	$900.00
Barus, Carl	1,340.50
Benedict and Talbot	989.40
Clark, H. L	7,982.80
Clark, Victor S	3,500.00
Concordance to Keats	4,500.00
Cooper, Lane	392.98
Crampton, Henry E	8,866.95
Davenport, C. B	1,389.00
Dodge, Raymond, and F. G. Benedict	1,618.15
Duesberg, Sabin, Shipley, and Wislocki, Pub. 223	10.12
Faust, A. B	1,200.00
Hedrick, H. B	1,396.60
Hill, R. R	2,600.00
Index to State Documents	2,882.61
Index U. S. Documents relating to Foreign Affairs	8,457.93
Johnson and York	1,762.48
Johnson, E. R., *et al*	3,785.24
Knobel and Peters, "Ptolemy's Almagest"	2,236.62
Moodie, R. L	3,500.00
Morgan and Bridges	1,400.00
Morley, S. G	2,855.66
Moulton, F. R	2,463.25
Osgood, C. G	8,428.25
Papers from Department of Marine Biology, Pub. 213	2,686.80
Reprint of "The Old Yellow Book"	1,444.04
Reprint of "Star Catalogue" by Lewis Boss	489.50
Classics of International Law	13,454.11
Shreve, Forrest	303.78
Sommer, H. O	500.00
Stager, Henry W	1,025.30
Wieland, G. R	5,376.55
Unallotted	7,394.75
	107,133.37
Paper in stock	20,818.54
	86,314.83

REPORT OF AUDITORS.

PHILADELPHIA, *November 22, 1915.*

The Executive Committee, Carnegie Institution of Washington:

DEAR SIRS: We respectfully report that we have audited the accounts of the Carnegie Institution of Washington for the year ended October 31, 1915, and found them to be correct.

The investment securities of the Endowment and other funds were examined by us and found to be in accordance with the general books of account. The cash on hand was verified by actual count and the balances in banks were confirmed by direct communication with the various depositories.

The income from the investment securities has been duly accounted for and properly approved vouchers were submitted for all payments made by the Administrative office at Washington. We did not audit the accounts of the various departments, since this is done by the Bursar under authority of your Committee.

The financial statements on pages 45 to 51, both inclusive, in the Year Book for 1915 correctly summarize the accounts of the Institution.

Respectfully submitted.

LYBRAND, ROSS BROS. & MONTGOMERY.

REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1915, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.*

D. T. MacDougal, Director.

The activities of the year have been rewarded by definite progress in the study of all of the groups of problems under consideration. Some of the more important results may be briefly summarized as follows:

Growth in plants takes place at the expense of definite or formative compounds, which are formed locally at a rate determined primarily by the influence of temperature on chemical velocity. These constructive processes may be masked or checked by imperfect respiration, and enlargement depends upon conditions favorable to water-absorption. Light breaks down the smothering acids resulting from incomplete respiration in cacti and thus facilitates the construction of formative material. The lessened acidity resulting from the action of light is a condition of increased absorption of water, so that light may accelerate growth in two different ways.

Improvements in auxographic instruments and the designing of glass screens of specialized transmissibility of light have been accomplished.

The readily varying permeability of protoplasm is referred to the interrelations of the disperse-phase and disperse-medium of the hydrophile emulsion colloids of which it is made up.

Repetition of the experiments upon respiration with temperature controlled to within 0.02° C. demonstrates conclusively that sunlight causes changes in the air, as a result of which respiration (as measured by excretion of carbon dioxide) is highest on days of high solar radiation, less on cloudy days, and least at night. Arrangements are being made for measurements of the electrical conditions of the air under identical conditions.

In the study of the possible phases of photosynthesis in plants solutions of carbon dioxide and potassium carbonate have been reduced to formic acid by exposure to light from a mercury-vapor arc in a quartz tube. Next a sugar-like substance has been obtained by exposure of formic acid to sunlight and to ultra-violet light. This substance gives the reactions of sugar and can be used as food by green algæ in darkness.

Succulent plants desiccated for long periods may show normal proportions of water-content, owing to the coincident respiration or oxidation of solid material.

The hydrolyzable carbohydrates of such plants starved for periods of one to six years were decreased, but the proportion of non-reducing sugars increased during starvation. Hydrolysis of cell-walls, deformation and peripheral thickening of the nuclei, and reduction of the

*Situated at Tucson, Arizona.

protoplast were included in the starvation phenomena. Some starvation effects remain after several years of restored normal conditions.

The reduction of transpiration or water-loss in desert plants is not one of maximum rate, but consists in a check or lessening of the rate earlier in the day than in other plants.

The densities of the sap of desert plants are lowest in species native to arroyos and ascend in a scale through those of cañons, rocky slopes, and bajadas to the highest values in saline areas.

The successions of plants which occupy an area originally bare finally reach a climax formation the nature and permanence of which are determined by climatic control. Four great vegetation eras, viz, Eophytic, Palæophytic, Mesophytic, and Cenophytic, can be recognized in the history of terrestrial vegetation.

The chief physical factors and their determinative effect upon vegetation at various altitudes from a low desert to the top of an insular mountain have been evaluated.

The field work necessary to a complete survey of the Cactaceæ has been brought to an advanced stage by expeditions to the West Indies, Brazil, and Argentina.

The Salton Sea receded about 50 inches during the year ending July 1, 1915, an amount in excess of that of the previous year. The total recession now amounts to nearly 40 feet or nearly one-half the original maximum depth. The total dissolved salts has increased from 0.32 per cent in 1907 to 1.37 per cent in 1915. The heightened salinity of the water has been followed by changes in the revegetation of the beaches and by the cessation of deposition of calcium carbonate on fixed objects near the surface. This implies changes in the marine as well as in strand organisms.

Preliminary examination of the playas, bajadas, streamways, lake beds, faults, and terraces of the Mohave Desert region has disclosed evidences of climatic variation and of movements of the surface which it is hoped may be interpreted to account for the origination, phylogeny, and successions of the vegetation which now characterize the region.

The desert rubber plant (*Parthenium argentatum*) under domestication has been found to show over 100 strains separable by habit, structure, form, and rubber content.

The studies of the rôle of the factors in a desert complex prove that the more divergent part of a population is eliminated by environic agencies, but this eliminating action is subject to various modifications.

The mutating stocks of beetles have continued to produce mutants as in previous years, one being an additional or second departure from the original. Another type of modification, consisting in alterations of the stripes on the elytra of beetles, which was first apparent as a small variation or departure, shows an orthogenetic progression, the new characters being genetically stable.

The year has been characterized by the most cordial cooperation on the part of a number of institutions, some of which have borne a share of the expense of researches carried on at the departmental laboratories, and cash donations to defray the expense of certain researches have been received.

EQUIPMENT.

The cages for testing environic effects on plants and beetles having become unsafe and unsuitable, a new suite was constructed, with bases of brick and cement and tops of cypress suitable for holding netting or glass, and temperature-control apparatus has been installed in several experimental units. The most notable addition to the equipment consisted of the new laboratory for phytochemical research.

The investigations of the last four years on the relation of light to organisms have clearly revealed the fact that the most hopeful point of attack of these highly complex problems is the study of the chemical changes produced by light. Such a study naturally requires chemical and physico-chemical investigations of a highly specialized nature. In accordance with these requirements a new laboratory was designed for the study of the chemical and physiological effects of light, and this was completed in November 1914.

The building, 50 by 28 feet, is of stone; the inner walls are pressed brick. It contains two laboratories equipped with water, gas, direct-current and alternating-current electricity, vacuum, air-pressure, and large fume hoods. There are also a small shop and preparation room, a machine room for vacuum and pressure pump, 4-horsepower motor generator set, water-still, etc., a study, and a capacious attic used for storage and in connection with experiments on the roof. One side of the main laboratory, 23 by 25 feet, is arranged and fully equipped for chemical work; the other side is devoted to work with plants, microscopic-work table, and the thermostatic apparatus for the investigations of the effect of sunlight on respiration. The other laboratory is a photo-chemical dark-room for work with artificial sources of light as well as sunlight, spectroscope and polariscope work, etc. On the roof there is an insolation deck, 30 by 15 feet, covered with sheet lead; this is virtually an open laboratory affording excellent facilities for special chemical and physiological experimentation with sunlight.

PHOTOLYSIS, RESPIRATION, HYDRATATION, AND GROWTH.

The Mechanism and Conditions of Growth, by D. T. MacDougal.

Auxographic records of the growth rates of seedlings of corn, wheat, and opuntia at the Desert and Coastal Laboratories include continuous tracings of the growth expansion of a large number of plants during the entire development of leaves and of segments of flattened stems.

Some individuals were followed without interruption for periods of 70 days under measured or controlled conditions.

The reduction and analysis of the data concerning growth in plants has made it possible to formulate some advanced general statements. The whole process of enlargement includes the synthesis, or solution of food material by hydrolysis of accumulated supplies, the conduction of solutions to the enlarging tracts and its conversion into the specialized formative material necessary for the growth of organs of all kinds. This is followed by the incorporation of the material in the plasmatic colloids and their derivative and accessory structures.

Photosynthesis (or other reduction processes), hydrolysis, and the final utilization of food-material in the construction of formative substances are chemical processes the velocity of which is so influenced by temperature as to be increased 2 to 7 times for every rise of 10° C. The delicate response of growth by changes in rate under variations of 1° to 2° C. support the inference that temperature is the dominant factor in controlling growth by its effect on the availability of the food-supply. This agency, of course, also affects the rate of conduction of food-material and of its introduction into growing masses, but in very much less degree than it exerts on chemical reaction.

The utilization of food-material, in which the carbohydrates are the most important constituent, includes some breaking down of the sugars, the initial changes being enzymotically induced, followed by oxidation of the waste or derivatives (organic acids) not actually used as building material. The rate at which the first stage of the process proceeds depends upon the removal of the acids, which not only check respiration, but also by their effect on the plasmatic colloids lessen the hydratation capacity or swelling power of plasma and cell-walls. The acid wastes are disintegrated by the action of light, with a resultant acceleration of respiration and of the construction of "formative material." The capacity of the growing parts to take up water is increased coincidently.

The above effects are well exemplified by the behavior of growing joints of opuntia, of which several hundred records are available. The daily history of a growing joint includes an acceleration in the forenoon, during which time the acid wastes are being broken down by light, the maximum rate of growth being reached after noon with the consumption of the accumulated food-material. The elongation slackens or proceeds according to the diminished supply, and with the coming of darkness may actually cease by the hemming action of accumulated acids. Actual shortening may ensue during the night because of decreased hydratation capacity resulting from low temperature and acidulation. The dawn brings the disintegrating effect of light on acids and the resumption of growth.

Light of the shorter wave-lengths (blue-violet rays) has a further possible effect on growth in that it coagulates or neutralizes colloids (suspensoids) and reduces their hydratation capacity, and may also possibly break down some nuclear substances. The radiation in question, however, has the least penetrating power of any part of the spectrum, and hence its action is most marked in minute organisms, or those with translucent membranes. Marked morphogenic alterations in the higher plants may be induced by illumination from a mercury-vapor arc in a quartz tube.

Methods and Material for Study of Fundamental Processes of Growth, by D. T. MacDougal.

Nearly all available data concerning growth of the higher plants have been obtained by a study of single organs of seedlings, measurements being made under conditions not capable of yielding conclusions of wide application, or which afford a basis of analysis of the contributory processes.

An inspection of the material available at the Desert Laboratory made it apparent that the flattened opuntias offered certain structural features and habits of growth which promised unexcelled opportunities for analyses of some of the physico-chemical processes of growth and to make exact measurements subject to well-defined corrections. The joints of these plants emerge as small flattened buds, thickly covered with ephemeral leaves, and they expand to a length of 15 to 20 cm. and a width of 8 to 16 cm. in about two months.

The growing joints are firm enough to give steady contacts with counter-weighted levers carrying a pen which traces the expansion or other change in volume continuously. The joints are complex as to morphogeny, but enlarge as simple but heterogeneous disks of plasmatic colloid against distensible membranes and fibro-vascular skeletons. The transpiration, stomatal action, respiration, and the major features of sugar content and acidity of these plants are known, so that it was possible to connect alterations in rate of growth with chemical conditions in the joint, a connection not hitherto adequately established. Instead of a single series of chambers with temperature control, it has been found most effective to establish separate small chambers at the various small experimental plants. Light screens of various transmissibility as described in the previous section have also been devised and constructed. The compound-lever systems used to obtain the auxographs of some of these plants were adjusted to record all variations in the dimension being measured. The slackened elongation rate and the shrinkages detected in the tracings, which in some cases extended for ten weeks without break, furnished evidence upon which important contributions may be made as to the relation of acidity and respiration to growth.

Influence of Light upon Growth and Development, by D. T. MacDougal.

The author began work on this subject in 1899 and completed an extensive study of the growth and development of plants in darkness in 1903. The conclusions reached at that time included a generalization to the effect that light does not exert an invariable effect on the rate of growth. The completion of studies of Richards and Spoehr at the Desert Laboratory, upon respiration and acidity, have now yielded some new views and gained some vantage-ground for a new attack upon the subject.

The organization of this work has required the testing of suitable sources of light and the construction of a suite of plane and parabolic silvered mirrors by Dr. Ritchey, of the Solar Observatory. The greatest technical difficulty that has been met and overcome, however, has been that of securing screens of glass by which light of certain wave-lengths only might be thrown on the experimental objects. A number of these have been obtained by the cooperation of Dr. H. P. Gage, of the Corning Glass Works, and as soon as testing facilities are organized these screens will be made available to other laboratories. Satisfactory formulæ have been found for a good monochrome red which removes all light of wave-length shorter than 0.61μ with a refractive index of 1.507; a yellow-red transmitting red-yellow and green to 0.53μ; a blue transmitting the blue violet from 0.52μ, and hence being complementary to the last; "uviol" transmitting the entire visible spectrum, and a "heat-absorbing glass" which absorbs the infra-red. The last-named has some promise of utility in glazing windows in warm countries.

The preliminary tests give some indication that the influence of illumination is due to the combined effect of wave-length, total energy, and relation to the absorption spectrum of chlorophyll. The most obvious results are of a morphogenic character, although the rate and amount of growth are doubtless affected.

The Relation of Soil Aeration to Plant Growth, by E. E. Free and B. E. Livingston.

Experiments with *Coleus*, carried out in the Laboratory of Plant Physiology of the Johns Hopkins University, appear to indicate that this plant requires a certain low rate of oxygen supply to the soil in which it is rooted. The soil-moisture content in these experiments was kept near the physiological optimum and almost constant, by means of auto-irrigators, and a somewhat elaborate system of apparatus allowed the oxygen supply to the soil of the cultures to be cut off and renewed at will. Stems and foliage were exposed to the greenhouse air as usual.

The first noticeable effect of cutting off the supply of oxygen to the soil was a cessation of water-absorption by the roots, as indicated by the fact that the soil ceased to take water from the irrigators.[1] This indication

[1]Livingston and Hawkins, Carnegie Inst. Wash. Pub. No. 204, 3–48, 1915.

was accompanied by cessation of growth and was soon followed by wilting. If wilting was not allowed to go too far the plants could be revived by renewing the access of oxygen to the soil. The injurious response was rapid and the revival slow. This study will be continued. It has a number of important relations to both theoretical and practical problems of the relations of plants to the soil solution.

Physiological Indices of Temperature Efficiency for Plant Growth, by B. E. Livingston.

The interpretation of climatological temperature data with reference to plant growth has received still further attention during the past year. Livingston and Livingston[1] have summed the normal daily mean temperatures above 39° F. for a large number of stations in the United States, for the period of the average frostless season, and have also summed, for the same period, the normal daily chemical indices of temperature efficiency (supposing that chemical reactions double in velocity with each temperature rise of 18° F.). They show that the two charts of temperature efficiency values thus obtained, tentatively representing the temperature influence for the entire period of the average frostless season, are remarkably similar, but differ in certain important details. Neither of these two methods of temperature efficiency summation has any direct physiological basis, and it is obvious that neither method can be regarded as plausible for the higher temperatures observed in nature; for both methods proceed on the supposition that plant growth should continue indefinitely to increase as the temperature rises, and this is well known to be in disagreement with physiological observation.

The publication of Lehenbauer's study of the relation between temperature and the rate of growth of the shoots of maize seedlings[2] made possible a first attempt to derive physiological indices of temperature efficiency for plant growth. Lehenbauer's graph of observed growth-rates for shoots of maize seedlings, for 12-hour exposures to maintained temperatures, was conventionally smoothed, by means of a spline, and the ordinates of the smoothed graph were measured for each whole degree Fahrenheit. The values thus obtained were then expressed in terms of the value for 40° F., taken as unity, and these numbers are tentatively regarded as indices of temperature efficiency for plant growth. In making the summations for the climatological study, each day in the period of the average frostless season is represented by the efficiency index corresponding to its normal mean temperature and all of these indices for the period are summed for each station considered. This method of summation has a theoretical advantage over those heretofore tested, namely, that it takes account of the existence of the physiological temperature optimum; the table

[1]Bot. Gaz., vol. 56, 349–375, 1913. [2]Physiol. Res., vol. 1, 247–288, 1914.

of efficiency indices here employed indicates that the growth-rate is the same for a temperature of 40° as for one of 116°, and that it is about 122 times as great for a temperature of 89° as it is for one of 40° F.

A Simple Climatic Index, by B. E. Livingston.

Various studies heretofore reported, bearing on the relation of climatic conditions to plant growth, have been aimed toward the expression of all climatic influences, for any given station, by a single numerical value. While this aim is a sort of ideal abstraction that must long remain quite out of reach, it appears that progress enough has now been made toward the dynamic analysis of plant relations, so that a first tentative approximation may be proposed. The present proposal involves the use of the precipitation-evaporation ratio of Transeau (which may be taken as a roughly approximate index of the water-relations of plants, so far as these are determined by climatic conditions) and the summation of the daily physiological indices of temperature efficiency (which is similarly considered as a measure of the temperature condition). The precipitation-evaporation ratio is determined for the period of the average frostless season, and this value is multiplied by the temperature efficiency summation for the same period. The climatic product thus derived is proposed as an approximate index of the normal climatic efficiency for plant growth, for the station in question. This value may be derived for a large number of stations and a climatic chart may be constructed from the data thus obtained, and such a chart exhibits several fundamental features not shown by the charts of any of the simple climatic indices. From the method of derivation it is seen at once that this compound climatic index becomes larger (1) with increase in the values of the normal daily temperature efficiency indices for the average frostless season; (2) with increase in the length of the average frostless season; (3) with increase in the total precipitation for the average frostless season, and (4) with decrease in the total evaporation for that season. Conversely the value in question becomes smaller with lower daily efficiency indices, with a shorter average frostless season, with decreased rainfall, and with increased evaporation. According to this compound climatic index, northern humid and southern arid regions are represented as lying in the same climatic zone.

Root Growth of Opuntia versicolor at Constant Soil Temperatures, by W. A. Cannon.

The temperature of the soil changes relatively slowly during the course of the day, and also the range is comparatively small, at the depths attained by the roots of most perennials of the Tucson region, including the cacti. Both of these conditions vary with the depth, among other features, and are accentuated in seasons of cloudiness and storm. In order to estimate the actual root growth of a plant, there-

fore, it is necessary to observe the rate of growth either at a constant temperature or with slight temperature range. Looking to this end, experiments were devised, of which the following is a summary of results now obtained, by which fairly constant soil temperatures were kept for periods of from 6 to 9 hours, during which time readings of root growth were made at intervals of from 30 minutes to periods of 3 hours each.

The series of experiments were conducted at the Coastal Laboratory, where in July the daily range of air temperatures is less than 10° C., and the daily mean is about 20° C. The plants were grown in glass tubes sunk in thermostats of the desired temperature, while the shoots were exposed to air temperatures. In the first series a temperature varying not more than 1° from 32.5° C. was maintained. Typical results at this temperature, with readings made every 2 hours, were as follows: 1.2, 1.2, 1.6, and 1.3 mm. In another experiment the following root growths, also at 2-hour intervals, were noted: 1.1, 0.9, 1.7, and 1.0 mm. These results were substantiated in other experiments.

A second and a third series, differing from each other only in the temperatures employed, gave results of which the following are representative. In the second series a temperature of the soil was used which did not vary more than 1° from 25.5° C. The roots were exposed continuously to this temperature for 9 hours, and readings were made at intervals of 9 hours. The increase in length of the roots for each 3-hour period was as follows: 1.1, 1.1, and 1.5 mm.

In the third series of experiments the soil temperature varied less than 1.5° from 20° C. Observations were made every half hour. During the entire period, 7½ hours, a total root growth of 1.8 mm. was made, which was slightly over 0.12 mm. for each half hour. An approximately constant growth-rate was maintained throughout the experiment.

From these experiments it appears that roots exposed from 7½ to 9 hours to a fairly constant soil temperature do not exhibit measurable decrease in growth-rate; but although the total root-growth is at a rate somewhat different from that observed in other experiments, the results, on the whole, are confirmatory of those previously obtained. The probable rate of root-growth in the habitat of the species can now be calculated with some accuracy if the daily course of the temperature of the soil at the depth attained by the roots of opuntia is known. Other factors, such as aeration of the soil and behavior of the shoot, exert a minor influence.

Soil Aeration and Root Growth, by W. A. Cannon.

Observations on the root-systems of perennials growing in the vicinity of the Desert Laboratory show that they may occupy different positions in the soil. Some root-systems are deeply placed and others

lie close to the surface of the ground. Studies on the possible immediate causes of such characteristic differences in root habit indicate that the temperature and the aeration of the soil may both play important rôles. For example, the roots of *Prosopis velutina* and of *Opuntia versicolor* show unlike temperature relations. The roots of *Prosopis*, in short, react to lower temperatures than do those of *Opuntia*. Further, it appears from thermographic records that the temperature of the soil at a depth taken by the roots of the former species does not suit the more shallowly placed roots of *Opuntia*. It is concluded from these observations that the vertical distribution of the roots of these species is directly related to the vertical differentiation of the temperature of the soil. It appears possible, however, that the relation to soil aeration of shallowly placed roots may differ from that of roots that penetrate deeply. To test this possibility and to determine the immediate effect of a variable air-supply on the rate of root-growth, several experiments have from time to time been carried out. The results, which have not been entirely consistent, may be briefly given. Increased shoot and root growth followed artificial aeration of the soil in certain instances, while in others the aeration appeared to produce no effect. When, however, the roots of *Opuntia* were kept at a constant temperature, the results with this species were more consistent. For example, in one series of experiments, the roots of *Opuntia* were held at a temperature of 32° C. for 8 hours, during which time a slow current of air passed through the culture in 2-hour periods, with the alternating 2 hours in which the roots were not aerated. At the same time observation was made as to the rate of root-growth of a control of the same species which was not aerated. The leading results, in brief, were as follows: the average rate of root-growth for 2-hour periods while aerated, average of 13 observations, was 1.59 mm.; the average rate of root-growth of the same root not aerated was 1.25 mm.; the average rate of root-growth of the control was 1.3 mm. It would therefore appear that artificial aeration slightly increases the amount of root-growth of *Opuntia*. Further observations on the reaction of the roots of *Opuntia*, not here reported, indicate that an insufficient amount of air may inhibit root branching. It seems probable, consequently, that the superficial root habit assumed in *Opuntia* is due in part to the favorable soil temperature, and in part to the relatively favorable conditions of soil aeration.

Periodic Variations of Respiratory Activity, by H. A. Spoehr.

The investigations in this subject have been continued with special attention to controlling temperature. The plants used for study were kept in an electrically controlled water thermostat, so that the temperature of the air surrounding the plants did not range more than 0.02° C. in

a day, nor in the course of an experiment lasting 20 days. The optimum temperature for these experiments was found to be 27° C. The number of carbon-dioxide determinations made during a period of 24 hours was increased to 4 and in some cases to 6. An apparatus has been constructed which automatically inserts and withdraws the CO_2 absorption tubes from the air-stream at any desired time. Thus greater accuracy is obtained in the analysis of the air passing over the plants, and the amount of personal attention and labor involved in the course of an experiment is considerably reduced. A larger variety of material has also been employed, including a number of bulbous plants and the shoots from the potato, as well as several fungi cultures grown on gelatine, especially *Aspergillus niger*. All these plants show the same phenomenon: a higher rate of carbon-dioxide evolution during the day than at night; the difference between day and night is great on days of high solar radiation, while on overcast days this difference is but slight. The progress of the investigations has been somewhat interfered with by the unfavorable weather conditions of the winter and spring, and especially by not being able to procure from abroad some instruments necessary for the study of the electrical conditions of the atmosphere.

Studies in Photosynthesis, by H. A. Spoehr.

In the course of the last three years many experiments have been carried out with a view to reducing carbon dioxide by means of light and of experimentally testing the Baeyer formaldehyde hypothesis. By use of ultra-violet light from a quartz mercury-vapor lamp, solutions of carbon dioxide and of potassium bicarbonate were reduced to formic acid. The solutions of alkaline bicarbonates yielded the largest amount of formic acid, which seems to be due to the higher concentration of the HCO_3 ion in solutions of these salts. A direct reduction of carbon dioxide or carbonates to formaldehyde was never obtained, even in the presence of nascent hydrogen. A reduction of formic acid to formaldehyde by means of light also could never be accomplished. On the other hand, it has been possible to synthesize a sugar-like substance directly from formic acid by means of sunlight or ultra-violet light. This substance, which was obtained in the form of a sirup, has many of the properties of a sugar, such as the reduction of Fehling's solution and Tollin's solution. Algæ develop in solutions thereof in the dark, and can use the substance as an only source of carbon. This substance is undoubtedly a very complex mixture, analogous to formose. The chemical investigations are now in progress. It has been found that not only is this sugar-like mixture synthesized in the light, but light also easily decomposes it, so that the final yield is never large. In the decomposing action, besides formic acid, there is formed a volatile substance giving many of the tests for aldehydes.

In order to determine whether formaldehyde condenses to sugar under conditions such as possibly exist in the green leaf, an extensive series of experiments is in progress with solutions of formaldehyde and very weak alkalis in the sunlight and at ordinary temperatures. Thus far there is no evidence that formaldehyde could condense to sugar in the plant leaf in the sense of the Butlerow reaction.

Hydratation Capacity of Plant Colloids, by H. A. Spoehr and H. W. Estill.

Previous work on the diurnal variation of the acidity of succulents has shown the necessity of determining the effect of varying concentrations of acids and alkalis on the hydratation of plant colloids before any clear idea can be gained of the effect of light on the growth of these plants. An extensive study of the effect of acids and alkalis on the hydratation of the colloidal material of various plants is now in progress. It has become evident that the total swelling of plants like *Opuntia blakeana* and *O. discata* in dilute solutions of acids, alkalis, and salts represents the summation of independent reactions of various material to these reagents. Thus, solutions of acids, alkalis, and salts influence the swelling and growth of these plants by affecting: (1) the hydratation of the protoplasts; (2) the material that goes to make up the cell-wall and fibro-vascular system; (3) the permeability and osmotic properties of the plasma-membrane. It has been found that these three factors can act independently and even in opposite directions. Great differences were found in these respects in different portions of the same cactus joint and between young and mature ones; the colloidal material of the former showed much greater swelling than the latter in all solutions, and the excess of swelling in acid media above that in alkaline media or distilled water was much greater in the young joints. Of interest is the observation that the colloidal material from mature joints which have been freed as much as possible from the fibro-vascular strands showed a diminution in volume in weak alkaline solution.

The Behavior of Protoplasm as a Colloidal Complex, by Francis E. Lloyd.

The presence of large water vacuoles in the vast majority of plant cells converts them into osmotic systems in which the behavior of the emulsion colloids as such is masked to a greater or less extent. It is, for example, a difficult, if not impossible, task to evaluate the hydratation alterations caused by various reagents because of the total change in volume of the cell resulting from a gain or a loss of water by the vacuoles usually referred to osmotic interchange or to change in permeability. Among other purposes before the experimental cytologist, he has to account for such change in terms of structure of the colloidal complex called protoplasm. To eliminate errors of observation possible when water vacuoles, being a distinct system, chiefly composed of solid-disperse-phase and liquid-disperse-medium, are present, cells

have been chosen from which such vacuoles are absent. The protoplasts of many (though not all) pollen-grains appear to satisfy these conditions. These offer ready-to-hand material, with certain disadvantages indeed, but such as are not too serious. These are chiefly due to the presence of the more or less rigid envelopes (extine and intine). In the future it may be found quite possible to eliminate them by using younger material. For the present, the observations which follow have been derived from the study of mature pollen, for the most part of *Eschscholtzia californica*.

Many pollens burst on being placed in tap-water. When the protoplasm is thus set free, an internal secretion of water is begun, in consequence of which the whole mass becomes a froth, suggesting that the formation of water vacuoles in the growing cell is the result of growth and not a method of increasing pressure. Inasmuch as no vacuoles are present, the bursting depends entirely on the hydratation capacity of emulsion colloids and not upon the presence of solutions of high concentrations, such as would be required to overcome the resistance of the envelopes. According to expectation, the hydrophile colloids constituting the protoplasm behave in certain respects as, *e. g.*, do the hydrocellulose content of certain tannin cells and the analogous mucilage of the mucilage cells of mallows and cacti, which, when allowed to, may absorb water with sufficient avidity to burst the cell wall. Thus, the protoplasm of pollen will swell and may burst the envelopes even in solutions of high concentration, either after initial shrinkage or so quickly that an initial shrinkage may be assumed to occur, if indeed it does; *e. g.*, pollen of *Gossypium* bursts in 0.45 N KNO_3 in 50 per cent cane sugar and 25 per cent glycerol. Similar behavior is shown by other kinds. Even in concentrated salts (*e. g.*, KNO_3), glycerine, etc., the protoplasm swells sufficiently to distend the envelopes in the course of 15 to 30 minutes, though it is preceded by partial or complete shrinking. Weak acids and alkali cause swelling and (when the concentrations are proper) bursting and the formation of coagula characteristic of each reagent.

Pollen which will not burst at once in water may do so (*Lupinus*) after about 2 hours' germination, when the pressure becomes sufficient to overcome the resistance of the thin membrane just at the apex of the pollen-tube, and it is important to note that minute water vacuoles which are present in the tube protoplasm at the time have no measurable influence. The bursting of the envelope, therefore, serves as one index of the hydratation capacity of the protoplasm, and, without disregarding others, serves to bring out many phases of behavior. The escaping protoplasm is variously distorted as it escapes, as a jelly would be under the same conditions, by the envelopes, and the observer is enabled to note the change or absence of change in the form of the suspensoids, and thereby to judge of their physical characters.

Structure of the protoplast.[1]—The cytoplasm appears as a colorless, glistening mass. Only a very slight lack of homogeneity allows the inference of "granulation." No water vacuoles and no solids are visible. On applying a concentrated salt solution (3/N KNO_3) swelling slowly follows initial shrinkage, during which an emulsion-like structure is optically accentuated.

A lipoid is present in amicronic dispersion and is apparently distributed throughout the whole of the cytoplasm. The alterations of surface tensions on swelling, on consequent pressure on the envelope (this being a possible factor), and on coagulation, causes changes in the degree of dispersion[2] and the lipoid becomes segregated into visible droplets, which are usually smaller toward the periphery (in 0.7/N. NH_4OH) and frequently absent from a peripheral zone (in KNO_3, 0.6/N). This behavior is strongly suggestive of that of the fluid disperse phase in relation to the fluid disperse medium of the protoplasmic emulsion colloid proper, and further that changes in permeability can be explained as changes in the size of the fluid suspensoids and in their spatial relations in the disperse medium.[3] Such changes may be reversible, as when a previous volume, following shrinkage caused by a salt, is restored, or irreversible, as when coagulation has occurred. Alterations in permeability could thus be caused by mechanical pressure, or application of salts, or other dehydratating agent (such as glycerine), hydratating agents (acids, alkalis), heat, or any other conditions which would temporarily or permanently alter surface-tension conditions, or the amount of water held within the critical colloid complex. The "normal" condition of the protoplast is one adjusted to the substances present in itself and in the solutions within the vacuoles, if these are present, so that the application of (*e. g.*) distilled water or water of lower concentration must produce changes in hydratation, and hence of permeability.

The mutual effects of two reagents, one a salt and the other acid or alkali, are of interest in this connection. A 10 per cent (or 1 per cent) solution of ammonia will cause the contents of a pollen-grain to escape in its entirety without visible damage (unless the swelling takes place too rapidly) in a few minutes. 3/N KNO_3 allows this swelling to take place only slowly, and just sufficiently in the stronger solution to cause rupture of the envelope. In the course of 40 minutes coagulation has set in. Similarly, 1/N HCl will first cause swelling (due to the initial diffusion of acid) and then coagulation, the intine being burst and the coagulum being more or less extruded in an irregular stream. In the presence of 3/N KNO_3, the swelling is sufficient only to burst the extine,

[1]These remarks apply to the cytoplasm of the vegetative cell, to which only attention has been paid till the present moment.

[2]Alkanet in alcohol-water, with minimum alcohol, was the reagent used.

[3]This view had occurred to Mr. E. E. Free at the time of a conversation with him during the progress of this work.

the intine remaining intact. The degree of dispersion must be different in the contrasted cases, and it is not impossible that such differences are analogous to those expressing changes of permeability.

The result of coagulation by one reagent is different from that caused by another. When the cytoplasm is irreversibly coagulated by formic acid, the gel, after drying, will swell less in ammonia than in formic acid. The coagulum formed in the presence of ammonia, which may be due to the pressure exerted by the envelopes on the swelling colloids, has a much softer consistency than that caused by acids. A coagulum is formed without more swelling than just sufficient to stretch the envelopes in very strong glycerine in the course of a few hours, and its consistency is again different from that caused by alkali. This coagulum will at once swell further and escape as a whole on the addition of ammonia, the volume of the coagulum being much greater than if caused by formic acid. Coagulation caused by acids takes place suddenly at certain concentrations of the reagent. It is always preceded by swelling, but this swelling is due probably to the lower initial concentrations which first reach the protoplasm.

The concentrations of acids and the consequent amount of swelling and the forms assumed by the coagula are so various as to prompt inquiry into the nature of their structure. One factor appears to be the resistance offered by the superficial layer of coagulum to further penetration of the reagent—this layer becoming a semi-permeable one. It would seem that the specific actions of acids on protoplasm may be due in part to coagulation effects imposed upon hydratation, and this possibility is not confined to acids, since there is some evidence that alkalis may also have a coagulative effect at certain concentrations in addition to the power to cause swelling. Whether the ammonia is the immediate cause or not, it is certain that the protoplasm of pollen can be caused to coagulate in its presence, and similarly in the presence of potassium hydrate ($\frac{1}{12}$ to $\frac{1}{2}$/N). Such behavior seems to be quite different from that of gelatine and similar colloids, so far as at present understood.

The evidence upon which the above is based supports the view that protoplasm is fundamentally a hydrophile emulsion colloid, of whose momentary interrelations of disperse-phase and disperse-medium its permeability is a function. The relation may be changed from moment to moment by hydratations and coagulations which, if irreversible, lead to death.

Chemical Changes accompanying Desiccation and Partial Starvation of Succulents, by E. R. Long.

The attempt to obtain individuals which would illustrate the metabolic changes taking place at intermediate stages of desiccation of succulents was begun in June 1914, when six healthy echinocacti were

taken up from the slopes west of the Desert Laboratory and placed on supports, three in the laboratory court exposed to full sunlight, and three within the laboratory in diffuse light in a room with a north exposure. The loss in weight was determined by weighing at intervals, and analyses were made after periods of approximately 5 and 8½ months of desiccation under the two sets of conditions.

The principal features of desiccation of the flattened joints of the opuntias native to this region being known to be something different from those presented by the globose echinocacti, it was deemed essential to follow a number of these plants through the earlier stages of depleted water-balance in order to compare the variations in weight and water-content with those observed in *Echinocactus*. The material consisted of 24 turgid joints of *Opuntia discata* taken from two plants growing near the chemical building of the Desert Laboratory on September 28, 1914. The separate joints were taken from terminal portions of the plant and were cut cleanly at the base in such manner as to be as nearly equivalent as possible in evaporative capacity. Six were arranged on a wooden support in an upright position in the open, exposed to the full illumination, the planes of the joints being north and south; six were placed near these, but in a horizontal position, being turned once every week, so that the two sides were alternately uppermost; six were similarly placed in an upright position in the diffuse light in the middle of the largest room in the main building of the Desert Laboratory, and six in a horizontal position.

The results of the analyses are as follows:

Prolonged confinement in diffuse light results in a decrease in density of sap in *Echinocactus*. Exposure in the open, with consequent rapid loss in weight, may be followed by an increase or by a decrease in the density of the sap.

Decrease in the density of sap is to be attributed to a disintegration of the carbohydrates, which, in *Echinocactus* No. 7, amounted to 13 per cent of the dry weight of the cortex. The destruction of material was extended to include the walls of whole masses of tissue in the cortex.

Increase in the density of the sap might result from rapid evaporation, which altered the proportions of water and dissolved substances, or by the addition of photosynthetic products.

The proportion of reducing sugars is greatest in the peripheral tissues of normal plants, in connection with the photosynthetic activity localized here, and decreases through the cortex to the central cylinder. The reduction which takes place in desiccation and starvation reverses the distribution of these substances, the greatest proportion after desiccation being found in the inner cortex and the total amount being reduced.

Non-reducing soluble sugars, which are present in only minute proportions, if at all, in normal echinocacti, are noticeable constituents of the sap of desiccated plants.

The acidity of the tissues is due to certain modifiable features of respiration. Acidity of plants which have undergone long-continued desiccation and starvation is low, since the amount of carbohydrate from which they are derived has been decreased.

Katabolism in extended desiccation and starvation eventually breaks down the plasmatic colloids and includes hydrolysis of the cell-walls of the cortex.

The loss in weight of *Opuntia* in full sunlight and in diffuse light is not very different during the first 35 days of exposure, and is practically the same after that length of time. The position of the flattened joints in the open may modify the rate of loss.

Opuntia desiccating in the open shows an increase in dry weight, but a decrease in hydrolyzable carbohydrate, while the acidity is not markedly different from the normal, though slightly less. Desiccation in diffuse light results in increase of acidity, increase of dry weight (not as pronounced as in the open), and decrease in hydrolyzable carbohydrate.

Reversible Changes of Form in Succulents, by D. T. MacDougal.

Gross measurements of joints of platyopuntias during their development and in succeeding seasons showed that these bodies were subject to reversible changes in length and width, as exemplified by the accompanying figures obtained from a joint of *Opuntia discata* (No. 3) at Tucson, in 1912, 1913, and 1914 (shortening indicated by bold-face figures):

Date.	Width	Length.	Date.	Width	Length
1912			1913		
May 9	6.0 cm.	7.0 cm.	Mar. 9	15.3 cm	17.2 cm
May 18	9.8	11.0	May 9	**15.2**	**17.0**
May 29	11.2	13.2	June 18	15.3	**17.0**
June 9	11.8	13.2	1914		
Sept. 24	15.2	16.8	Apr. 3	16.2	17.2

A number of mature joints of this succulent were placed in bearing with precision auxographs of a type devised by the author in 1902, in which both expansions and contractions, magnified 20 to 50 times, are recorded. The changes of size of a mature joint, such as those indicated in March 1913, consist mainly of swelling by increased absorption of water made possible by disintegration of acids in the sap. This does not proceed at an even rate, but is most rapid in the first half of the day, being greatest from 11 a. m. until 2 p. m. During the remainder of the day this action would fall off and actual shortening might occur at night as a result of increased acidity and heightened transpiration. These reversible changes in form also take place in young joints,

and accompany growth, running parallel to its course and being determined in greater part by identical causes.

That the water balance is actually decreased at night and increased by day has been found by Mrs. E. B. Shreve, who says of a cylindropuntia:[1]

"It was found, under conditions of average transpiration, such as occur in the greenhouse in summer, that the water intake at night is less than the outgo, while during the day the intake is greater than or at least equal to the outgo. . . . An examination of the water-content of stems from plants in the open and from the greenhouse showed that the highest water-content is at 5 p. m. after the close of a bright day, and the lowest just before daylight the next morning, with an intermediate amount at noon."

The Effect of Desiccation on the Structure of Echinocactus wislizeni, by J. G. Brown.

The effect of desiccation on the structure of living tissues has been studied chiefly by zoologists who were interested in the ability of the rotifers and other invertebrates to survive extended periods of drought.

The capacity of plants, such as certain algæ, pteridophytes, and liverworts, to endure periodic drying, is even more remarkable than the ability of the rotifer to resist desiccation, but there is a paucity of literature on the changes of a cytological character in the cells of these plants resulting from conditions of drought.

The object of the investigation here reported was to determine changes in structure brought about by continued deprivation of water, and to discover any evidence of recovery on the part of the plant when, after a period of desiccation, it was again subjected to normal out-of-door conditions. Preliminary to the study of the desiccated material a careful examination of the structure of the normal plant was made. The principal conclusions warranted by the facts obtained are as follows:

Extended desiccation and starvation made no alteration in the integument of *Echinocactus*, but in a plant which had been thus treated for 73 months the cuticle was thicker than normal, while the outer walls of the epidermal cells were thinner. Cytoplasm and nuclei in the epidermal system were reduced, but new cork layers were being formed as in normal plants. Cell division was seen in the epidermal layer at the bottom of the grooves of the stem. The stomata remained permanently open and many were in a collapsed condition. Guard-cells of stomata differed from the normal in having the anterior walls thinner as compared with the posterior walls.

The palisade layer was thinner in desiccated than in normal plants of *Echinocactus*. The cytoplasm was reduced to small masses in the angles of the cells and the nuclei were variously deformed and reduced

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[1] Rept. Dept. Bot. Research, Carnegie Inst. Wash., Year Book for 1914, pp. 98, 99.

in size. Vacuoles had disappeared from the nucleoplasm and a thickened granular layer was present in the peripheral portion.

The most pronounced effects of desiccation and starvation were exhibited by the cortex of *Echinocactus*. The changes noted as having been seen in the palisade tissue were followed by the entire disappearance of the protoplasts and the hydrolysis of the cell-walls. The consequent disintegration of cell masses formed lacunæ as large as 8 c.c.

Some of the effects of desiccation and starvation were to be found in the medulla of *Echinocactus* plants under treatment, but to a lesser degree. Disintegration of cell-walls was observed in restricted areas. No change appeared to be produced in the vascular bundles by desiccation and starvation.

Early stages of the changes noted above, such as the reduction of cytoplasm and nuclei of cells, deformation and peripheral thickening of nuclei, and hydrolysis of cell-walls, were found in plants which had been desiccated in diffuse light for only 10 months.

An *Echinocactus* which had been desiccated for 42 months and then placed under normal conditions in the soil for 22 months did not entirely regain the normal condition. The epidermal system was fairly normal, excepting irregularity in proportional thickness of anterior and posterior walls of stomatal guard cells. Nuclei of the palisade cells were below normal in size, and only one was seen that had regained normal shape. The peripheral, thickened, granular layer was still present in many cases. The cortex also retained irregularities of cell-wall and nucleus, as effects of the starvation and desiccation. Recovery was most advanced in the outer part of the cortical region. Cell-walls in the outer cortex varied from 2 to 10 micra in thickness, while in the inner cortex the variation was from less than 1 micron to over 20 micra. The inner cortex of this recuperating plant was characterized by some nuclei which were larger than the normal.[1]

The General Course of Depletion in Starving Succulents, by D. T. MacDougal.

A series of tests to determine the rate, course, and extent of the water-loss in massive succulents was begun in 1908. Selected individuals of *Echinocactus*, *Carnegiea*, and other plants with a relatively large water-balance, growing in the Tucson region, were taken from their habitats and placed upon stands which supported the plants at the height of a meter in such a manner that the light exposure was normal as to angle. Some were put in this position in the open, exposed to the full force of the sun, and were subject of course to the high midsummer temperatures of the region. Others were placed in laboratory rooms in which the illumination was from ordinary side-windows, and the temperature was rarely altered by artificial heat, being in general

[1]See MacDougal, Long, and Brown. End results of desiccation and respiration in succulent plants. Physiol. Researches, vol. 1, No. 6, 1915.

under more equable conditions than that to which the plants in the open were subjected.

The course of desiccation under the conditions named has already been described in several papers. Certain features in the variations in weight of the plants under observation, however, remained without adequate explanation. Among these is to be included the fact that the rate of water-loss decreases more rapidly than the ratio of succulence, or proportion of water present to the area of the transpiring surfaces.

Among the survivors of the original lot of plants taken for the test was one large *Echinocactus* which had been taken from the soil in November 1908 and kept in a shaded room for more than 6 years.

The following conclusions as to the water relations of such large succulents are established by the examination of this material:

Echinocactus in diffuse light may lose as much as one two-thousandth part of its weight in one day, immediately following the excision of its root-system. The same plant 6 years later, under equivalent conditions, except that its weight had been reduced nearly a third, lost no more than 1 part in 17,000 of its weight in one day.

An *Echinocactus* weighing 38 kg., of which 90 to 95 per cent may be estimated as water, lost 3.5 kg., or one-tenth of its total water, in the first year of isolation in diffuse light. In the sixth year the loss was one-twentieth of the water-supply at the beginning of that year.

Echinocacti in the open lost 38 to 45 per cent of their original weight during the period from June to November inclusive. Individuals in the diffuse light of the experimental rooms lost 7 or 8 per cent in the same period.

Echinocactus is capable of growth in the apical region, in plants in which water-loss and disintegration of the carbohydrates (including hydrolysis of the cortical walls) has reached an advanced stage.

The rate of loss in weight of an *Echinocactus*, largely due to evaporation, is not correlated with the degree of succulence (proportion of amount of water present to superficial area of body) or with the density of the sap, but is to be attributed to morphological causes.

The difference in behavior of *Echinocactus* and *Opuntia* in desiccation and starvation is correlated with definite physical features. *Echinocactus* has a globoid stem consisting largely of thin-walled cells, in which the accumulated food-material is in the form of soluble carbohydrates. Solid material and accessory colloids are noticeably lacking. The flattened joint of *Opuntia* is composed of a network of fibrovascular tissue. The fundamental tissue is rich in slime or mucilage, and somewhat higher in total hydrolyzable carbohydrates than is the fibro-vascular tissue. The loss of water from the large, globose stems of *Echinocactus* is much more affected by illumination than in the flattened stems of *Opuntia*. The course of respiration in the thin stems of of *Opuntia* is such that acids formed during the process are present

in greater proportion and vary more widely through the day than in the large echinocacti. Some connection with the hydratation of the slimes or mucilages is suggested.

Isolated individuals of succulent species survive varying periods when separated from a moist substratum. If the conditions for photosynthesis are inadequate, death may result from starvation. The disintegration of solid material in diffuse light may be such that the proportion of water in the tissues may be but little changed after several years of depletion.

SOME SPECIAL WATER RELATIONS OF PLANTS.

Plane Porous Clay Surfaces for Use in Atmometry, by B. E. Livingston.

The first porous-cup atmometer to be described was that of Bellani (1820), who employed what was essentially a porous cup with a plane circular upper surface and with the remainder of the wall impervious to water. The evaporating surface was that of a circular disk of porous clay closing the top of a metal cylinder, the latter filled with distilled water and connected to a reservoir below. This form of surface is exposed in practically the same manner as is a free water surface, yet the Bellani type of instrument encounters none of the difficulties met with in the operation of open pans of water. Nevertheless, this form of atmometer has failed to attract attention.

After some experimentation a satisfactory form of Bellani plate has been obtained, consisting of a circular disk of white, porous porcelain, 77 mm. in diameter, mounted across the large end of a glazed porcelain funnel. The apparatus is made as a single piece, the funnel and the disk being continuous and of the same material, but the lateral surface is heavily glazed externally. Wherever atmometric studies are to be related to water-loss from plane surfaces this modification of the porous cup may be employed.

Influence of Solar Radiation as a Drying Agent, by B. E. Livingston and E. S. Johnston.

Further progress toward the obtaining of satisfactory black porous spheres for the radio-atmometer has been made and a small number of usable pieces have been available for the summer of 1915. The black spheres heretofore obtained have generally proved unsatisfactory in various ways, and experimentation in the manufacture of these difficult pieces is being continued.

The records furnished by the radio-atmometer (a white and a black sphere operated side by side) in the open and in various intensities of shade have been critically studied for the summer climate of Baltimore and for that of Tucson. The instrument proves to be considerably more sensitive to the drying action of sunshine than is any plant so far tested, and it promises to be amply sensitive for ecological studies of solar radiation as a desiccating influence.

Auto-Irrigation of Pots of Soil for Experimental Cultures, by B. E. Livingston.

As has been reported, the porous-cup auto-irrigator furnishes a means for automatically maintaining the water-content of a given soil mass very nearly uniform for long periods of time, and it allows the ready measurement of the rate at which water is absorbed by the soil mass in question, as this rate fluctuates with the rate of water-loss by plant transpiration or by direct evaporation from the soil surface. With small amounts of soil and small plants one or more of the 12.5 cm. cylindrical cups used in the porous-cup atmometer have proved satisfactory, but the joining of a number of these small cups together, so as to avoid possibility of air-leakage, is somewhat uncertain, so that larger cylinders were desirable. These have now been obtained, the new size being about 5 cm. in diameter and 35 cm. long, thus allowing the use of a much deeper pot for the plant cultures than has heretofore been possible, without burying the stoppered opening in the soil. Placed horizontally, these larger porous cylinders furnish a satisfactory means for automatically maintaining the soil-moisture content in shallow culture-boxes.

The Progress of Wilting as Indicated by Foliar Transpiring Power, by A. L. Bakke and B. E. Livingston.

By means of the method of standardized cobalt chloride paper (a modification of the method of Stall) the march of foliar transpiring power was determined during progressive wilting of the plant. As the water-content of the plant decreases, foliar transpiring power decreases also, but as temporary wilting occurs and becomes more pronounced the rate of decrease in transpiring power becomes less rapid. At about the time when permanent wilting (in the sense of Briggs and Shantz) is attained, the value of the index of foliar transpiring power suddenly increases markedly, soon attaining a secondary maximum and then finally falling to zero, as the leaves die and desiccate. This secondary maximum in foliar transpiring power, as wilting progresses, has been pointed out by Leclerc du Sablon and others, though not in exactly this connection. Its detection by means of hygrometric paper may be of value in determining when permanent wilting actually occurs, or the occurrence of this secondary maximum may be taken as a criterion for detecting the physiologically critical point for which permanent wilting has been an approximate criterion.

Foliar Transpiring Power and the Darwin and Pertz Porometer, by S. F. Trelease and B. E. Livingston.

The direct method of measuring the transpiring power of leaves by means of standardized cobalt-chloride paper was employed in a study of the diurnal march of this physiological condition in leaves of wandering Jew (*Zebrina*) grown in the greenhouses of the Laboratory of

Plant Physiology of the Johns Hopkins University. Simultaneously, and with similar plants, the diurnal march of the permeability of the leaves to air-flow under pressure was also studied, by means of the F. Darwin and Pertz porometer. This instrument is calculated to measure the degree of stomatal opening from time to time, and if this feature is indeed the controlling condition in its operation, then the results obtained should be capable of interpretation to show the diurnal march of stomatal diffusive capacity in the sense of Brown and Escombe.

The results obtained from these parallel series of observations are similar in that both methods agree in showing the same kind of daily march, the values of both indices rising to a maximum in the day and falling to a minimum in the night. The range of variation, however, between the minimum and maximum is generally somewhat greater for the indices of stomatal diffusive capacity (derived from porometer readings) than for those of transpiring power (derived from the hygrometric paper tests). It appears that the porometer readings do furnish data for deriving the stomatal diffusive capacity, at least in these *Zebrina* leaves, but that this diffusive capacity can not be considered as quite proportional to transpiring power, as has been pointed out from earlier studies carried out in cooperation with the Desert Laboratory and as has been emphasized by Renner, conditions other than that of stomatal diffusive capacity are surely influential in determining foliar transpiring power. It is clear, however, that stomatal capacity is the main condition influencing transpiring power in such leaves as were here used.

It should be emphasized in this connection that transpiring power and the actual rate of transpiration are not at all the same thing; the former represents simply the group of *internal* conditions influencing the latter rate, which is of course greatly influenced also by a group of external conditions, such as the evaporating power of the air, etc.

The Autonomic Movements and Water-Relations of Cacti, by Edith B. Shreve.

The results obtained in previous years on movements of stems of *Opuntia versicolor* have been further tested and extended to other species of cacti. The data have been divided into two main parts, the first of which traces the causes of the movements as far as changes in turgidity, which are in turn due to periodic differences between water-intake at the roots and water-loss by transpiration; the second includes extended measurements of transpiration and of water-intake, which were undertaken with the aim of finding the causes of the variations in these phenomena. The first part has been made ready for publication and contains the following summary:

(1) Ten species of *Opuntia* and also *Carnegiea gigantea* have been found to show seasonal movements of the branches, which consist of a drop during desiccation and a rise during subsequent recovery, and these movements have been correlated with turgidity changes.

(2) The form of the adult cactus plant and the position of its branches are determined by the water-relations existing during the period of growth and secondary thickening of its various parts and not by any peculiarities residing in its growing-point or its mode of initiating lateral branches.

(3) *Opuntia fusicaulis, O. leptocaulis,* and *O. versicolor* were measured for a short-period movement, which consists of an upward movement during the daytime and a downward movement at night, under normal conditions of temperature, light, soil, water-content, and evaporative power of the air.

(4) A detailed study of *O. versicolor* showed that this short-period movement is influenced by temperature, light, evaporative power of the air, and the water-content of both soil and tissues, separately as well as in various combinations. But the influence of these factors is an indirect one, acting through other intermediate processes.

(5) The day-to-night movements have been shown to be caused directly by turgidity changes in the stems.

(6) *O. versicolor* is less turgid at night than in the daytime, as is shown by the fact that the plant absorbs more water through its roots in the day than it loses in the same time by transpiration, and at night it loses more than it absorbs. This is the opposite of the behavior shown by non-succulents which have been studied.

In this paper no mention is made of a possible correlation between acidity and the movements, because further experimentation has thrown doubt upon the existence of such a correlation, and surely shows that if a relation exists it is by no means a simple one. In the Year Book for 1914 (page 98) it was said:

> "Plants were placed under controlled conditions where an increase or decrease of acidity could be predicted and their movements measured . . . a downward movement was always accompanied by an increase in acidity and an upward movement by a decrease in acidity."

The predictions referred to were made on the basis of the results of other workers; but later, when tests were made on the material used for the experiments, it was found that the acidity changes under conditions of high temperature and darkness did not agree with the predictions. Consequently the statement quoted above from last year's report does not hold for all conditions of temperature and light.

The acidity results which were obtained from this work show that, at least for the time of year when the tests were made (April to June), *O. versicolor* shows a marked increase in acidity when kept at 90° F. in darkness for 8 to 16 hours. Plants were placed under the controlled conditions at the close of hot, clear days. Many determinations were made, so that there is no doubt in the mind of the experimenter about the correctness of the results for the conditions and material

used. The non-conformity of the results with those obtained by Dr. H. M. Richards on the same material (see Year Book 1911, p. 66, and 1912, p. 66) is probably due to a difference in the stage of metabolism which existed at the time the plants were placed under controlled conditions. Until this matter is given further investigation it is obviously impossible to draw conclusions regarding the relations existing between acidity changes and movements, or acidity changes and transpiration.

Data from the transpiration studies, the second main division referred to above, are now being assembled and include the results of many new experiments as well as those reported upon last year. The following is a provisional summary of the results as far as they have been elaborated:

(1) Progressive desiccation of soil and tissues in *Opuntia versicolor* is accompanied by a change in the relative transpiration (transpiring power). This change is of such a nature that, while relative transpiration is greater by night than by day when the plants are turgid and supplied with plenty of water, by the time extreme desiccation is reached the relative transpiration for the day is greater than for the night. The change in relative transpiration is brought about largely by a decrease in the absolute night transpiration.

(2) Experiments with severed joints show that it is the water-content of the tissues which determines the transpiring power and that the water-content of the soil is responsible only as it influences the condition of the tissues. The characteristic day-to-night changes in transpiring power take place for several days after the joints have been cut from the roots; consequently, it can not be changes in the amount of water absorbed which cause changes in the transpiring power.

(3) Simultaneous measurements of water-intake at the roots and of transpiration show that, under normal turgid conditions, transpiration-rate is not the major factor governing the amount of intake.

(4) Thus, from the results given under 2 and 3 above, it appears that there exists some internal factor, or factors, controlling both transpiration and absorption.

(5) The absorption capacity suggests itself as a possible internal factor causing changes in water-intake and transpiration. Measurements of the amount of distilled water absorbed by cylinders of tissue cut from the stem show that water-absorbing capacity of the tissues is correlated positively with the water-intake by the roots, and negatively with transpiring power. So far these measurements have been made for plants under normal conditions only.

(6) Further experiments confirm the statement that, under normal conditions of light and temperature which exist during the 24 hours, cylinders of tissue cut from joints show the greatest swelling capacity when their acidity is lowest, and vice versa.

(7) The acidity changes in these plants at high temperatures make necessary an investigation of the absorbing capacity of tissues which have been kept under certain controlled conditions, before any conclusions can be drawn concerning the connection between acidity and the transpiration or root-absorption behavior.

The Relation of Altitude and Habitat to the Transpiring Power of Plants, by Forrest Shreve.

During the month of June 1915 work was begun upon the relative transpiring power of some 30 species of perennial plants of the encinal region of the Santa Catalina Mountains. The method of standardized hygrometric paper, recently elaborated by Livingston, was employed, making it possible to secure readings in the field from plants growing in their normal environment. The species used in this work were selected with a view to representing all of the physiological types in this richly diversified vegetation, and also with a view to being able to compare the transpiring power of the same plant at different elevations. In order to make adequate comparisons between different plants it was found necessary to take an hourly series of readings throughout the day on each of the individuals investigated. The hygrometric-paper method was found inadequate for the measurement of the low transpiration-rates of *Agave, Yucca,* and *Opuntia,* although a very thin grade of paper was used. It was also impossible by this method to measure the water-loss from the upper sides of the leaves of several sclerophyllous trees. In these cases comparisons were secured for the lower surfaces alone, while in the majority of cases the behavior of upper and lower surfaces was averaged.

Differently situated individuals of the same species, growing at the same altitude, were found to exhibit differences of transpiring power—the plant in situations of highest soil-moisture content having the highest coefficients. Species characteristic of the streamways, and confined to them, were found to have much higher coefficients than the species characteristic of the adjacent upland and slopes. Among the different types of plants investigated at 5,000 feet, marked differences were found in the coefficients of transpiring power and slight differences in the daily march of the coefficients. When plants of the same species were compared at different elevations, but in similar topographic sites, there were found to be differences in the coefficients and also in the daily march. In a comparison of the behavior of the mesquite (*Prosopis velutina*) the maximum is found to occur earliest at 2,400 feet (8 a. m.), later at 4,400 feet (10 a. m.), and still later at 5,000 feet (11 a. m.). The behavior of *Calliandra eriophylla* is similar in having an early maximum at 2,400 feet, but some individuals at 5,000 feet exhibit a late maximum coincident with that of evaporation. A comparison of the bellota (*Quercus emoryi*) at 5,000 and at 6,000 feet showed the highest

coefficient of transpiring power to precede the highest evaporation at the former elevation and showed the two to coincide at 6,000 feet.

These data confirm our knowledge of a check to the rate of transpiration which is applied before the daily maximum of the evaporative power of the air. This check appears to be applied later and later in the day with increasing altitude, and to be eliminated at 5,000 feet for some species and at 6,000 for others. The actual rates of water-loss, and sometimes even the coefficients of transpiring power, are higher at the lower altitudes. The "reduction of transpiration," of which so much has been said regarding desert plants, is not to be discovered in the maximum absolute water-losses, which are greatest in the desert plants, but is to be detected in the time of the daily check in rate.

ENVIRONIC RELATIONS: PHYTOGEOGRAPHY.

The Osmotic Pressure of Vegetable Saps in relation to Local Environmental Conditions in the Arizona Deserts, by J. A. Harris.

An extensive series of cryoscopic determinations of the osmotic pressure of saps of four principal growth-forms, trees and shrubs, dwarf shrubs and woody twiners, perennial herbs, and winter annuals, characteristic of the foot-hills, cañons, cliffs or rocky slopes, bajadas, arroyos, and saline areas, was made for the purpose of ascertaining whether or not any definite relation between sap-density and environment prevails. The data secured indicate that the lowest osmotic pressure is to be found in the sap of plants from the arroyos. As might be expected, the highest concentrations were found in the plants of the salt spots. Eight determinations of plants from this habitat gave an average of 37.1 atmospheres, but a very wide range of variation is exhibited among the species as well as within any single species.

The species of the bajadas without exception stand next to those of the saline areas in concentration of sap, and the lowest concentrations are to be found in the plants taken from the beds of the arroyos or washes. The principal results are summarized in the following table:

Osmotic pressure in atmospheres of growth forms in five habitats of the Tucson region.

Growth forms.	Arroyos.	Cañons.	Rocky slopes.	Bajadas.	Salt spots.
Trees and shrubs	17.7	22.4	22.0	34.7	47.9
Dwarf shrubs and twiners	16.6	21	21.1	23.9	34.2
Perennial herbs	13	14.4	16.8	19.7	....
Winter annuals	12.9	13	15.3	21.1	23.6

Climatic Cycles and Succession, by F. E. Clements.

The further analysis of the fundamental processes and principles of succession has led to a clear recognition of the distinction between the ontogeny and phylogeny of plant formations. The ontogenetic process is represented by the unit succession or *sere*, in which develop-

ment begins with a bare area—rock, water, or soil—and progresses slowly but inevitably to a climax. The latter is regarded as the organic unit of vegetation and hence is designated by the term "formation." The climax or formation is a mature or adult form, the development of which is seen in the successional sequence. The nature and permanence of the climax are determined by climatic control. As a consequence, each formation persists until an effective change of climate causes its disappearance in the old region with its concomitant invasion into a new one, or until it gives rise to a new flora through evolution. Such changes are phylogenetic in nature, and are of the first importance in unraveling the successions of the geological past. Thus, as in the case of the individual plant, ontogeny in vegetation comprises the periodic reproductive process of the formation as an organism under the same climate, while phylogeny deals with the change of one climax into another, or its differentiation into two or more under the stress of the changing climate.

The phylogenetic study of plant formations, *i. e.*, the course of succession in the geologic past, has been made possible only by the recent great advances in climatology. The existence and recurrence of climatic cycles has been established beyond question, and it has proved possible to recognize a complete series of such cycles from the familiar annual one through sun-spot and deformation cycles of varying duration and intensity to the grand deformation cycles extending over millions of years. Each of these has an appreciable effect upon vegetation, but the major cycles alone are able to produce phylogenetic changes. The phylogenetic events of the first importance in the history of vegetation are those recorded in the evolution of new floras and hence of climax units, characteristic of the four great vegetation eras, viz, Eophytic, Paleophytic, Mesophytic, and Cenophytic. Hence, it is possible to recognize four primary periods in the terrestrial history of vegetation and to divide the geosere, which comprises the whole course of succession on the globe, into corresponding eoseres, namely, Paleosere, Meseosere, and Ceneosere. The flora of the first was pteroid, and it seems probable that several climax formations were already differentiated, corresponding to the respective dominance of Cordaites, Lepidodendreæ, and Calamites. The dominants of the Meseosere were gymnospermous, and the number of climaxes seems to have increased with climatic differentiation. The Ceneosere was initiated by the change from gymnosperms to angiosperms, and the course of the succession began to approximate that which is seen to-day. The eosere of the Eophytic period is wholly hypothetical, but the conclusion is unavoidable that it was marked by climaxes of a bryophytic or pteridophytic nature.

Next in importance to the phylogenetic changes which characterized each era were those produced by the glacial-interglacial cycles of

great periods of glaciation, such as the Permian and the Pleistocene. Instead of the evolution of a new flora and new climaxes, each advance and retreat of the ice produced a corresponding shifting of the climax zones in front of it. This shifting of the zones by which each was first replaced by successively earlier or lower preclimaxes, and these in turn by successively later or higher postclimaxes, constitutes a clisere, *i. e.*, a successional development from one climax to another. The clisere differs from the eosere in that no new flora is evolved, but existing climaxes merely shifted, and differs from the sere in being a succession of climaxes instead of developmental stages which terminate in a relatively permanent climax. The consistent application of developmental principles has confirmed the original assumption that all features of vegetation are the structural results of developmental processes, and hence furnish direct evidence of the operation of the latter. This has long been known to be the case in hydroseres, where the successional movement from open water to the climax is relatively rapid and symmetrical. However, these have been thought to constitute exceptions and not to furnish the rule. The careful scrutiny of climax formations throughout western North America during the last three summers has shown the principle to be of universal application, in time as well as in space. Even in the most static community, not only have the relations of the various dominants and subdominants been found to record the past development and to suggest that of the future, but it has also proved possible to recognize developmental areas throughout, minute and fragmentary as they often are. This is especially true in the climax zones of mountains, where surface and soil are extremely diverse and where great differences occur in the smallest contiguous areas. This successional analysis of dominance has made it clear that no two dominant species are exactly alike in their demands, while it has justified their grouping into communities on the basis of the similarity of their responses. From this has come the far-reaching conclusion that the dominant furnishes the key to the developmental study of vegetation, as well as the chief objective of the experimental attack which must accompany the latter. This has been definitized in the concepts of the consocies and the consociation, which are respectively developmental and climax communities controlled by a single dominant. Consocies fall naturally into developmental units, or associes, and consociations nto climax units or associations, both of which are due to similarity of physiological response. Thus, the recognition of the dominant as the basis of investigation has made it possible to utilize both autecologic and synecologic evidences in the study of vegetation, and to harmonize them both in terms of development.

A Successional Study of the Transitions between Climaxes, by F. E. Clements.

The use of developmental methods in the analysis of the climax formations of western North America has been continued during the summer of 1915. For a number of reasons, especial attention has been given to the transition zones between climaxes, particularly grassland and scrub, which cover the largest areas and show the greatest complexity. It has been found possible to standardize the results of such study for purposes of comparison by dealing directly and chiefly with the dominants and subdominants, *i. e.*, consociations and societies, of the contiguous climaxes. The first transition studied was that from the subclimax and climax prairies of eastern Nebraska and South Dakota to the short-grass plains of western Nebraska and eastern Wyoming. The alternation of dominants was first traced through northern Nebraska and parts of South Dakota to the plains, and then eastward through the sandhills of eastern Nebraska to the prairies again. The second region traversed was from northeastern Kansas to western Oklahoma, southward through the Panhandle of Texas to the Pecos River, and northward through eastern New Mexico to the Great Plains. The change from the *Bouteloua-Bulbilis* grassland to the *Prosopis-Aristida* savannah was first traced southward through Texas, and then checked in the reverse direction through New Mexico. A similar study was made of the transition between the desert scrub of the Southwest and the sagebrush formation of the Great Basin. This was first traversed from south to north from southeastern California to Nevada and Utah, then southward through eastern Utah and northward through western Colorado. Consequently, the successional relations of the climax dominants were noted scores of times, within as well as between successive climaxes. This not only afforded a constantly recurring check on the developmental history and the regional limits of the different climaxes, but also furnished decisive evidence of their climatic relations, especially with reference to the effect of future cycles. In this connection, much attention was paid to the competition responses in the ecotone between two or more dominants, and suggestive results were obtained in the attempt to use these responses as an index of present as well as of future climatic tendencies. Finally, an endeavor was made to test more rigorously the assumption that the habitat, like the formation, has a developmental history which ends in a permanent or mature condition determined by the climate.

The Vegetation of a Desert Mountain Range as Conditioned by Climatic Factors, by Forrest Shreve.

The work on the vegetation and physical factors of the Santa Catalina Mountains, which has been in progress for five years (see previous annual reports), has been elaborated up to the close of 1914 and published. The principal aim of this work has been to correlate the cli-

matic gradients of the mountain with the vertical differences of the vegetation. The mountain is characterized by desert on its lower slopes, by open evergreen-oak forest or encinal at its middle elevations, by pine forest above 7,000 feet, and by fir forest on the highest summits. Nearly all the species of plants are distributed so definitely with relation to altitude and habitat as to indicate that they are controlled in their movements and establishment by the operation of physical factors. The major differentiation of vegetation on the mountain is controlled by the factors which are in turn due to differences of altitude. The minor influences of slope-exposure and other topographic features cause local departures from the normal altitudinal gradient of vegetation, but these departures are merely such as to bring a given type of vegetation to an altitude higher or lower than that in which it is commonly found. Rainfall, soil-moisture, evaporation, and temperature have been studied at a series of stations reaching from 3,000 to 9,000 feet, at 1,000-foot intervals. The influence of slope-exposure on the conditions of soil-moisture and evaporation and the influence of topography in modifying the theoretical conditions of temperature have been particularly emphasized. The rainfall at the forested elevations is about 2½ times as great as it is on the desert, and the soil-moisture in the driest portion of the year is from 5 to 15 times as great, according to the slope-exposure. The evaporation is 3 to 4 times as great on the desert as it is on the summit of the mountain. The daily and seasonal temperatures are approximately 30° F. lower on the summit of the mountain than on the desert, while the frostless season is about half as long in the former as in the latter locality.

The ratio of evaporation to soil-moisture in the Santa Catalinas has already been commented upon (see Annual Report, 1912), and it appears to be the climatic feature which limits the distribution of the mountain plants at the edge of the desert. The upward limitation of desert plants appears, on the other hand, to be due to the operation of winter temperature conditions. It has been necessary to study the vertical gradient of temperature with special reference to the operation of cold-air drainage, which is very pronounced throughout the lightly forested or unforested portions of the mountain. For instance, the difference between the minimum temperature in the floor of a cañon at 6,000 feet and on the summit of a ridge at the same elevation has been as great as the normal difference between two stations of the same topographic site located nearly 3,500 vertical feet apart. Comparisons have been made between the climatic gradients of the Santa Catalinas and gradients derived from the Weather Bureau stations of southern Arizona, situated at different elevations in the valleys of the adjacent region. These comparisons are particularly significant with respect to the rainfall conditions, showing that the isolated mountains have a greater rainfall at 4,000 and 5,000 feet than localities in

the valleys at the same elevations. The coldest temperatures of winter at 8,000 and 9,000 feet are much milder on an isolated mountain, surrounded by desert, than they are at the same elevation on extensive plateaus. These and other features of the work on the Santa Catalinas have emphasized the difference between the altitudinal gradient of physical conditions on a small mountain and on a larger gently tilted plain which lies through the same elevations. The relation of environmental conditions to the vegetation is likewise different in the two. Both of these cases form an important part of the general problem of the relation of vegetation to climate.

The Vegetistic and Floristic Features of the Pinaleno Mountains of Southern Arizona, by Forrest Shreve.

During September 1914 an expedition was made from Tucson to the Pinaleno Mountains (Mount Graham), in Graham County, Arizona. These mountains are 60 miles distant from the Santa Catalinas, reach an elevation of 10,500 feet, and are built chiefly of gneiss. The object of the visit was to compare the general vegetistic features of these two desert mountains, which are of approximately the same age, in nearly the same state of dissection, and constructed of the same mineralogical material. The gently rolling summits of the Pinaleno range lie chiefly above 9,500 feet and are clothed with a fir and spruce forest much greater in extent than the analogous portion of the Santa Catalinas. The numerous cañons which have eaten the edges of the summits are very precipitous. This circumstance has limited the extent of the pine forests and has presented conditions favorable for the high occurrence of the trees and shrubs which are characteristic of the encinal, or evergreen-oak, region. The existence of well-watered cañons and steep slopes has caused a pronounced interdigitation of the highland and lowland vegetations, so that the plants of streamways are carried nearly 1,000 feet lower than they are in the Santa Catalina Mountains, while the encinal is carried about 1,200 feet higher than it extends in the Santa Catalinas.

The existence of lofty and sharply dissected alluvial aprons on the northeast side of the mountains, falling to an elevation of 2,800 feet at the Gila River, and the existence of a sub-level plain on the southwest side, lying at 5,500 feet, causes marked dissimilarities in the vegetation of the lowest slopes on the two sides and also influences the vertical limits of the vegetations on the two faces of the mountain.

Inasmuch as the Pinaleno Mountains had not been visited by botanists for 40 years (since the Whipple Expedition), a full collection of all plants in suitable condition was made, with the cooperation of Professor J. J. Thornber. Many plants of the Sonoran-Sinaloan region, characteristic of the lower elevations of the Santa Catalinas, were not found in the Pinaleno Mountains, while in the higher elevations of the

Pinalenos were found many plants common to the Rocky Mountains of northern New Mexico, but not in the Santa Catalinas. Some of the latter species are found in the Pinaleno range only at elevations greater than any in the Santa Catalinas, but the great majority are found at elevations which do exist in the latter range. Owing to the similarity of climatic and other environmental conditions in the two mountains, the absence of these species from the Santa Catalinas would appear to be due to causes other than those of the physical environment. It will at least be possible to test the ability of these species to survive when an extension of their ranges is attempted.

Distribution of the Cacti with reference to the Rôle Played by the Relation of Root Response to Temperature, by W. A. Cannon.

Studies on the reaction of the roots of the cacti to certain environmental features, particularly the temperature of the soil, indicate that the root-temperature relation may be of special importance among the complex factors which determine the geographical distribution of the family.

Numerous garden cultures and experiments, carried on at the Desert Laboratory and the Coastal Laboratory, show that the species of cactus from the Tucson region require a relatively high temperature for an effective growth-rate of the roots. For example, the average hourly increase in length of the roots of *Opuntia versicolor* has been found to be about 0.3 mm. at 20° C., 0.6 mm. at 30° C., and 1.0 mm. at 34° C. At a temperature of 16° C., however, a growth-rate of only 0.07 mm. was observed.

The period in which the soil-moisture and temperature is suitable for the active growth of the roots of *Opuntia versicolor* and other cacti, in the vicinity of the Desert Laboratory, is restricted to about six weeks of each year. This is limited both by soil-moisture and soil-temperature. At a depth of 15 cm. the mean maximum temperatures for midwinter and midsummer of a typical year were 8.1° and 34° C., respectively. The mean maxima at a depth of 30 cm. were 12.2° and 33° C. for January and July. The course of soil-moisture, as shown by numerous studies, is such that there are two moist and two dry periods each year. The moist periods are in winter and in summer. In the intervening seasons, particularly in the fore-summer, the soil at a depth of 15 to 30 cm., or that occupied by the roots of the cacti, carries an insufficient amount of moisture for root absorption. From these environmental conditions it happens, therefore, that in winter low soil-temperatures prevent root-growth, and in the earlier part of summer the soil is not sufficiently moist for the growth of roots. In short, it is not until the coming of the rains of midsummer that in the Tucson region the roots of the cacti experience conditions favorable for their growth. Root-growth of the cacti ceases with the coming of autumn

either because of excessive dryness of the soil or because of its low temperature.

From the observations on root-growth and root-relations of the cacti as summarized in the foregoing paragraphs it appears that the presence of the cacti in the Tucson region is in large part to be attributed to the occurrence of rains at a season when the soil is also warm. These observations, also, make it possible to suggest that a similar root-soil relation may obtain among the cacti of other regions, explaining on the one hand their presence in such regions, and suggesting on the other the causes for their sparseness, or absence, in yet other regions where they might be expected to occur.

The cacti occur mainly in the southwestern United States, in the uplands of Mexico, and in Central and South America. A feature of the climate of the regions inhabited by the cacti is the relatively scant rainfall, which also is periodic. Whatever may be the character of the winter climate, that of the summer season is marked by more or less precipitation. Thus, at Tucson, for example, about 54 per cent of the annual rainfall is in summer. At Tehuacán, on the Mexican plateau, which has been characterized as the richest region known in cacti, 72 per cent of the precipitation is in summer. In portions of Central and South America where the cacti occur, rains constitute a feature of the climate of the warm season. We may therefore make the generalization that in regions inhabited by the cacti their presence is in large part to be related to the coincidence of precipitation and high temperature, by which favorable growth conditions, particularly of the roots, are insured.

In regions where the rainfall either is relatively light or wanting in summer, and cacti occur to a limited extent, it is not impossible that the summer rainfall is not the minimum for the species, or that the species are adjusted to a lower temperature relation than that found in the cacti in southern Arizona. The latter alternative prevails with *Opuntia ramosissima* of the Mohave Desert, as indicated in another section, as well as that of certain extra-regional cacti, not here reported.

Rate of Root-Growth of Opuntia ramosissima and its Possible Ecological Significance, by W. A. Cannon.

Opuntia ramosissima is native in the Mohave Desert. An important characteristic of the climate of this desert is its low annual rainfall, only 14 per cent of the total occurring in summer; and it has been shown in another section that a relatively low summer rainfall does not favor active root-growth. The fact that cacti occur in the Mohave Desert, therefore, suggests special conditions. Among the possible factors which might operate to bring about the survival of cacti in the Mohave, one only need receive attention here, namely, the possibility that the root-soil temperature response is such as permits this species

to develop in the winter rains. In this case it would point either to a relatively warm winter soil or to a somewhat different temperature response than that already found in the cacti of southern Arizona. To test the validity of the latter possibility, a series of experiments was planned in which the root-growth of *Opuntia ramosissima* was to be compared with that of *O. versicolor*, from the vicinity of the Desert Laboratory, as a control.

In the experiments each series was continued about 8 hours at soil-temperatures varying between 19° and 31° C. as extremes. The range of temperatures employed and the variation were probably about what the species experience in their proper habitats. The following summary of the experiments can be given:

Experiments with *Opuntia versicolor:* (1) With soil-temperatures ranging between 21° and 27° C., the root-growth, in 8 hours, was 2.1 mm. (2) With temperatures from 19° to 27.5° C., the root-growth was 2.3 mm. (3) The root-growth at temperatures between 23° and 30° C. was 2.7 mm.

Experiments with *O. ramosissima:* (1) The root-growth, in 8 hours, at soil-temperatures between 19° and 27° C. was 3.3 mm. (2) At soil-temperatures between 19° and 27° C. the root-growth was 3.2 mm. (3) At temperatures ranging between 19° and 25° C. the root-growth was 1.8 mm. (4) The root-growth at temperatures between 23° and 31° C. was 3.4 mm. (5) At temperatures between 20° and 25.5° C. the growth was 4.2 mm.

These experiments, and others, indicate that the roots of *Opuntia ramosissima* at soil-temperatures below "optimum" and above 19° C. increase at a somewhat faster rate than do those of *O. versicolor* at the same temperatures and under the same conditions. The difference in rate between the two species is approximately 33 per cent.

Further studies on the reaction of the roots of *O. ramosissima* to soil-temperatures under 20° C. indicate that the minimum temperature for efficient growth-rate is probably lower than in *O. versicolor*. For example, in 2-hour periods, and at soil-temperatures ranging from 12° to 17° C., the roots of *O. ramosissima* increased 0.2 and 0.5 mm. in length, while those of *O. versicolor* grew, in one case, 0.1 mm., and in another not at all.

It would appear, therefore, from these observations, that the roots of *Opuntia ramosissima* from the Mohave Desert grow somewhat more rapidly at parallel temperatures than do the roots of *O. versicolor;* and, especially, the roots of the Mohave species appear to have a fairly active growth-rate at relatively low temperatures. It would not seem impossible, therefore, that the roots of the species in the Mohave Desert (1) grow during seasons of relatively low temperatures, and (2) that the roots may penetrate the ground relatively deeply.

EREMOGRAPHY: THE SALTON AND MOHAVE DESERT REGIONS.

The Recession of the Salton Sea, by D. T. MacDougal.

A series of gage-readings of the level of the water is taken weekly by officials of the Southern Pacific Railway, and the data have been sent to this Department. It appears from these records that the recession was but 2 inches in July 1914, 19 inches in August and September 1914, 5 inches in October 1914, 6.5 inches in all during the following November, December, January, and February, 7.5 inches in March and April 1915, 4 inches in May 1915, and about the same in June 1915.

The total for the year ending July 1, 1915, was about 50 inches, which is about the average annual recession for several years previous, but is more than in the previous year. The erratic rate of recession is to be attributed to local rains and to the overflow from irrigation systems. The irregularities noted above make it difficult to follow the occupations and successions of the beaches now being exposed.

It is to be noted that the calcium deposition indicated by the chemical analysis no longer takes the form of deposits on stems and other emersed objects.

Composition of the Salton Sea Water, June 8, 1915, by A. E. Vinson.

The annual analysis of the water of Salton Sea has not been completed at this time, but several determinations of considerable interest are available. The total solids have increased 16.8 per cent and now amount to 1,377.4 parts per 100,000. This is somewhat less concentration than has occurred in former years, but a considerable volume of fresh water flowed into the Sea from the Colorado River last winter. The constituents that have been determined are given in the following table:

Composition of Salton Sea Water, June 8, 1915 (in parts per 100,000).

Total solids	1377.4
Sodium	441.60
Potassium	5.12
Sulphuric (SO_4)	174.47
Bicarbonic (volumetrically)[1]	16.62
Carbonic total (gravimetrically)[1] (11.98 CO_2)	11.92
Oxygen consumed[1]	0.208

[1]Determined by Dr. H. A. Spoehr.

The elements show a fairly uniform concentration from year to year, with the exception of calcium and potassium. Calcium has been deposited in the form of tufas, but the history of potassium is less evident. In 1912 there was no concentration of this element and the following year there was a loss, although sodium had concentrated 18.8 and 19.3 per cent, respectively, for the years under consideration. In 1914 the disappearance of potassium, which had been so evident for several years, ceased, and this element showed almost the normal

concentration. During the past year potassium has been coming back and shows a rate of concentration far in excess of that of the other constituents. The fresh water received from the Colorado probably accounts for this in part, but more likely potassium has been returned to the water by the decay and disintegration of organic forms and of tufas that had been deposited by them. The behavior of potassium is shown very strikingly by the potassium-sodium and the potassium-total solids ratios in the last two lines of the table given below:

Annual composition and rate of concentration of certain constituents of Salton Sea water.

Year.	Solids.		Sodium.		Potassium.		Calcium.		Magnesium.		Sulphuric SO_4.		Ratio K:Na 1:48.3.	Ratio K:solids 1:158.
	Amt.	Inc.	Amt.	Inc.	Amt.	Inc.	Amt.	Inc.	Amt.	Inc.	Amt.	Inc.		
		p. ct.		p. ct.		p. ct.		p. ct.		p. ct.		p. ct.		
1907	364.8	....	111.05	....	2.30	....	9.95	....	6.43	....	47.60	....		
1908	437.2	17	134.26	20.9	2.78	20.8	11.87	19.2	7.63	18.7	56.74	19.2	1:48.3	1:157
1909	519.4	16	160.33	19.4	3.24	16.5	12.70	6.9	8.96	17.4	65.87	16.0	1:49.5	1:160
1910	603.8	21	189.28	18.0	3.53	8.9	13.67	7.6	9.84	9.8	76.36	15.9	1:53.6	1:171
1911	718.0	19.0	227.81	20.3	3.81	7.9	15.62	14.2	11.68	18.7	91.67	20.0	1:59.8	1:188
1912	846.5	17.5	270.71	18.8	3.81	0.0	17.28	10.6	13.62	16.7	106.83	16.5	1:71.1	1:222
1913	1,002.6	17.7	323.08	19.3	3.45	−9.4	19.75	14.2	16.22	19.1	124.65	16.6	1:94.0	1:288
1914	1,179.6	17.5	381.47	18.8	4.01	16.2	22.22	12.5	19.03	17.3	148.10	18.0	1:95.1	1:294
1915	1,377.4	16.8	441.60	15.7	5.12	27.6	.....	....	.....	....	174.47	17.8	1:86.0	1:269

Interpretation of Travertine Record of Blake Sea, by D. T. MacDougal and Godfrey Sykes.

An outlying mass of fragmental granite projects from a spur of the Santa Rosa Mountains into the Cahuilla Basin in southeastern California, the crest of the rocks rising above the ancient shore-line of Blake Sea, which filled the basin to a level something above that of present high tide in the Gulf of California.[1] This cape is designated as "Travertine Point" in our publications, as the surface of the granite boulders is covered to a varying depth with dendritic and lithoid tufa. Some marks and figures, presumably carved by Indians in the travertine, have long been known and were seen by us on our first visit to the place in 1906. In the continuation of our work on the Salton Sea it was realized that these figures might possibly yield some evidence as to the duration and variations of the ancient Blake Sea and of the smaller modern Salton Lake.

A visit to the formation was accordingly made in March 1915, and a careful inspection showed that the number of carvings on the rock was very large, and that some, made in the earlier layers of travertine, have been coated over to such depth that they may be made out only in the most favorable illumination or shading. Others show as deep furrows with weathered surfaces, visible at a hundred yards or more, while none of recent origin have yet been found.

[1]See plate 1, The Salton Sea. MacDougal *et al.*, Carnegie Inst. Wash. Pub. No. 193. 1914.

A slice of the travertine extending across four lines of a complex pictograph and down to the granite base was cut out and the surfaces of the sample are now being polished and prepared for critical examination by skilled lapidaries in London under the personal supervision of Mr. Sykes. It is now clear that the carvings were not made in the granite, but in the travertine, and extended study may be necessary to determine the depth at which the figures were made and what deposition and weathering has since taken place. This fact favors the presumption that Blake Sea was a fluctuating body of water and not a continuously receding one. The final proof of the matter will rest chiefly upon biological evidence concerning the activities of organisms in connection with the deposition of tufas to which the botanist may be expected to contribute. The whole body of evidence to be obtained by the study of this material promises to be of prime importance in determining the climatic cycles and geological successions of plants in the Mohave Desert region.

General Features of Vegetation in the Mohave Desert, by Forrest Shreve.

In the autumn of 1914 and the spring of 1915 a general reconnaissance was made of the vegetistic features of the Mohave Desert and of the region which lies between it and southern Arizona. The Mohave Desert is dominated by an open stand of microphyllous shrubs, and the principal differentiating feature of its climate is the occurrence of rain only in the late winter and early spring. The area is sharply contrasted with the Tucson region, where the succulents form such a large element in the vegetation and the chief climatic feature is the bi-seasonal rainfall. The more elevated portions of the Mohave Desert adjacent to the fringing mountains of its southern and western boundaries are characterized by a richly diversified assemblage of shrubs, by the arborescent *Yucca*, and by a small number of cacti. Throughout the remaining portion of the area, below an elevation of 4,000 feet, the dominant plants are *Covillea tridentata* and *Franseria dumosa*, and over extended areas these are often the only perennials to be found. *Covillea* occurs in all topographic situations and in a wide range of soils, in marked contrast to its more restricted occurrence in the vicinity of Tucson. *Franseria* is not wholly coextensive with *Covillea*, being very uncommon on slopes which have rock *in situ*.

It is true of the Mohave Desert in general that the minor topographic features are without a marked influence on the character of the vegetation. For example, the open stand of *Covillea* on a bajada is usually found to extend without any modification onto the adjacent slopes of the mother mountain; the shrubbery found along small streamways is no more dense than it is elsewhere and contains no distinctive species; the edges of dry lakes can be approached without change in composition or density of vegetation up to the lake bed itself; the north and

south slopes of hills and low mountains are also without differences of vegetation. These statements are not true of the more elevated parts of the Mohave, but each of them holds true below about 4,000 feet, and in all of the features mentioned the Mohave area differs greatly from southern Arizona, where all slight topographic differences are accompanied by dissimilarities in the vegetation. It is only in the largest mountains that the vegetation exhibits a differentiation due to altitudinal climatic changes. Many mountains which rise 2,000 to 3,000 feet above the desert floor are strikingly similar to the desert itself in their vegetation. The bajadal slopes are also identical through a vertical range of 3,000 feet. The principal vegetistic differences from an elevation of 4,000 feet down to the level of the Colorado River lie in (1) the dissimilarity of the texture and perhaps of the soluble mineral content of the soils which lie nearest the dry lake-basins and those which lie nearer the surrounding hills or mountains, and in (2) the special features of the sandy areas. The fine alkaline soils which lie nearest the dry lakes are covered by *Atriplex*, while the coarser and presumably less alkaline soils of the bajadas are dominated by *Covillea* and *Franseria*. Areas with sandy soil always exhibit differences from adjacent non-sandy areas, even when the two are topographically equivalent. The most striking features of the sand are the low and open stands of *Covillea* and *Franseria*, the presence of perennial and annual grasses, and the great abundance of ephemeral herbaceous plants.

The most striking feature of the vegetation of the Mohave Desert, so far as investigated, is the slight amount of habital differentiation which it exhibits. This condition is closely related to the severity of the physical environment and to the highly specialized behavior of the few species of dominant plants involved in the vegetation, each of which is capable of enduring a wide range of conditions.

Climatic Changes, by Ellsworth Huntington.

A preliminary reconnaisance of the principal basins in the Mohave Desert region and to the northward was made during the earlier part of the year. The purpose of this work was to determine whether more detailed study another year will furnish an adequate basis for a climatic scale extending from the Tertiary to the present time, and sufficiently accurate to serve as a standard of reference for other parts of the world. Such a scale has been prepared by Penck, for example, on the basis of glaciation in the Alps and elsewhere. Glaciation, however, tends to destroy the records of past events more than to preserve them. Hence the attempt to use it as the basis for determining the number, nature, and probable duration of periods having one kind of climate or another is fraught with great difficulty. In a desert region such as that which drains to Death Valley, on the contrary, the records of past events

are subject to a minimum degree of destruction. The general tendency is to preserve the evidence of one period by covering it with the deposits of another. Thus long series of deposits are formed which contain a full climatic record, if only it could be read. In most desert regions such records are accessible only in small fragments where their borders have been eroded, or by means of deep borings which of necessity disclose the nature of only a minute portion of a given deposit. In the Death Valley drainage area the deposits are fortunately eroded to an unusual depth in many places, or else have been upturned by recent faulting, and can be studied with great ease and thoroughness. There is, perhaps, no other part of the world where the prospects are so bright for obtaining a complete record of all the climatic changes, both large and small, from the later part of the Tertiary era through the entire glacial period to historic times.

In addition to the main purpose of framing a climatic scale, the present work in the Death Valley drainage area serves two other purposes. One is to test the old criteria for the determination of past climatic conditions and to devise new criteria. The other is to determine the relation of each new fact to the various hypotheses advanced in explanation of climatic changes. Only a preliminary reconnaissance has in most cases been possible during the present year. One of the most important lines of study, namely, a correlation of the glacial phenomena of the Sierras with the various types of evidence in the desert at their base, has not yet been begun.

The Effect of Climate versus Earth Movements, by Ellsworth Huntington.

Terraces and other alluvial deposits are of special importance as possible evidences of climatic changes, because no other type of evidence seems to be so widely spread. The great difficulty in interpreting them lies in the fact that similar features have repeatedly been supposed to be the result of movements of the earth's crust. The Mohave Desert is a particularly good region in which to study the matter. On the south the desert is bordered by the great San Andreas fault, along which the San Francisco earthquake took place, and on the west by the still greater fault at the eastern base of the Sierra Nevadas. Along both lines extensive movement has taken place in recent times. Hence here, if anywhere, terraces due to earth-movements ought to be well developed. Yet such is not the case. Although most interesting and peculiar features have arisen along the fault zones, terraces are not important except where the climatic conditions are appropriate according to the hypothesis set forth in "Explorations in Turkestan" and "The Climatic Factor." A phase of this problem has been investigated by Mr. Free, as described below.

An Ancient Bajada of the Great Basin Region, by E. E. Free.

Brief announcement of certain generalizations concerning the bajadas or débris-aprons of mountain ranges in the Great Basin and in the arid regions generally was made in the report of this Department for 1914. The essential conclusion was that these bajadas appear to be composed of distinct superposed elements and to indicate a record of alternating erosion and deposition around the mountain base. Further work has been confirmatory of this generalization and has brought out, in a striking way, the great development, wide distribution, and uniform character of the third, or sub-Recent, of these superposed bajadas. This surface has now been identified in all parts of the Great Basin and has been traced in nearly all of the major river valleys and over many of the mountain passes. It constitutes one of the most important physiographic elements of the Great Basin region, and its remarkable smoothness and regularity of grade suggest its completion during a long period of substantially uniform conditions.

Stream-cuttings into this ancient surface are everywhere of the flat-floored, steep-sided type previously described. The base to which these newer cuttings is graded seems to differ little, if at all, from that of the ancient surface, the difference being rather one of the curvature of the gradient. This fact and the uniformity of the physiographic elements over an area so wide and so varied make it impossible to consider the physiographic changes as the result of structural movement, changes in lake-levels, or other local causes. It is very probable that the cause lies in climatic changes and that significant evidence regarding the course of these changes can be obtained by closer study of the physiographic elements described.

The ancient bajada is well developed on the northern slope of the San Bernardino Mountains at the southern border of the Mohave Desert, southeastern California. Here the Mohave River has cut a typical steep-sided channel through the beds of the ancient bajada and these beds are exposed for a horizontal distance of over 100 miles. An intensive study of this area is in progress, and especial effort is being made to discover paleontological evidence which will enable the determination of the age of the ancient bajada.

The Stages of Development of Playas, by Ellsworth Huntington.

The temporary lakes known as playas are peculiarly well developed in the area draining to Death Valley. Some are completely flooded to a depth of a foot or more every year. Others contain large areas which have not been flooded for centuries, and which are being eroded by the wind. Some are floored with clay, and others with deposits of every degree of salinity up to almost pure crystals. Two important problems present themselves for solution. The first is the determination of the physical character of playas in various stages. In the

area under discussion it will probably be possible to find almost every stage of development, and thus to form a typical series to which playas in other parts of the world may be referred. The second, and more important, problem relates to the chemical composition of the deposits. The various chemical precipitates, such as soda, potash, lime, gypsum, borax, and others, which are laid down when salt lakes evaporate, are most puzzling because they do not follow the laws which seem to be deduced from laboratory experiments. The presence of minute organisms is doubtless in large part responsible for this, but the reduction to the playa stage with its alternate drying and flooding may be an important factor. The marked climatic fluctuations indicated by other lines of evidence suggest that the playa stage has been much more common than is generally supposed.

The Curtailment of Rivers by Desiccation, by Ellsworth Huntington.

Three main rivers, the Mohave, Owens, and Amargosa, drained to Death Valley at the height of the glacial period. Practically no surface water now reaches it. The process by which each of the three rivers has been cut off is typical of what has happened in almost every arid region, and therefore needs no elucidation. Owens River reached Death Valley through a chain of from three to five lakes, which were greatly expanded at the time when the river was largest. The Mohave and probably the Amargosa appear to have had few or no lakes along their courses at the time of their maximum development. Now, however, they are again and again interrupted by lakes or playas which owe their origin to the deposition, by tributaries, of detrital material in the form of fans.

The Agreement of Botanical, Chemical, and Physiographic Evidences of Climatic Pulsations, by Ellsworth Huntington.

Perhaps the most important single feature of the year's climatic work has been the correlation of diverse types of evidence in respect to the climatic changes of the past 2,000 years. A study of the chemical composition of the salt water of Owens and Pyramid lakes, by H. S. Gale and J. C. Jones, shows that the lakes must have overflowed and been fresh not much more than 2,000 years ago. Old strands indicate that the fall from the outlet level has been pulsatory, that is, the lake level has fallen, then risen toward, but not generally to, the old level, and then fallen again. This has been repeated several times. A comparison of the strands with the curve of growth of the sequoia tree which grows only 50 miles from Owens Lake, shows that the periods of high water in the lakes correspond closely with those of rapid growth in the trees. The correlation is so close that it is possible to date a given strand within a century or less. Moreover, the same series of strands can be detected not only at Owens and Pyramid, but at Mono Lake,

which had no outlet. This suggests that in time we may be able to assign approximately correct dates to all the score or more of strands around the various lakes. This will go far toward giving a correct time-scale for the climatic variations of post-glacial time.

In addition to this, the character of the various strands gives a clue to the kind of climate prevalent at any particular period. For example, the strand of 1350 A. D. indicates particularly stormy conditions with phenomenally high winds, a conclusion which agrees with historic accounts of western Europe.

The Death Valley Series, by Ellsworth Huntington.

As a basis for work in the immediate future, Death Valley furnishes a peculiarly inviting field. The bottom of that deep depression has alternately contained a lake or playa, or has been dry for protracted periods. The evidence of this is found in a series of thousands of feet of clays alternating with gravels. Toward the end of the glacial period, at a time not yet determined, these deposits were uplifted and tilted in such a way that they are exposed for many miles and can easily be studied. A preliminary examination suggests that they present a record of several glacial *epochs* preceding the four which are usually recognized as constituting the last glacial *period.* There has not yet been time to work out the full series, nor to ascertain whether any beds are repeated by faulting. It is certain, however, that the deposits point to even greater climatic complexity than is indicated by the phenomena of glaciation. The only known series at all comparable is the uplifted lake beds of Seistan in eastern Persia, which are described in "Explorations in Turkestan." The Death Valley beds are better than those at Seistan, for they are thicker and pass into solid rock at their base. The change from soft clays to solid rock, together with other changes which take place at that point, suggest not only that the end of the Tertiary era was marked by a great transition, as is generally recognized, but that the transition was extremely rapid and that the biological effect must have been correspondingly intense. Further study of these beds from the physical, chemical, and biological considerations is of the greatest importance.

GENETICS AND VARIOUS SPECIAL INVESTIGATIONS.

Transmission or Recurrence of Environic Effects in Phytolacca, by Francis E. Lloyd.

Certain effects, such as distortion and discoloration of foliage (obtained at Carmel) and morphological alterations of inflorescences and contained structures (obtained at Tucson), allowed the test of their inheritability. (See report for 1914.) The first generation from plants with abnormal foliage has shown no indication that the condition is inherited. On the other hand, one individual of the parent

generation, grown under glass, produced normal foliage early in the season, while later leaves show the abnormal characters. Examination of the affected areas of the leaf shows that within them the secondary physiological responses of the palisade and sub-palisade tissues have been suppressed and the structure remains therefore in an embryonic condition. This would seem to indicate that we are dealing with a "physiological" disease.

Negative results have also followed from the study of the second (F_1) generation from seeds produced by abnormal green fruits of the Tucson plant No. 1. All the progeny appear normal at present.

This year a departure from the normal, consisting in the production of very narrow lanceolate leaves, was synchronously entered upon by a small number of plants (in lot No. 131) at Tucson and Carmel. While this may be an expression of the general leaf-distortion above and previously noted, the only feature noticeable is the change in shape due to the reduction of the transverse measurements.

The Genetic Analysis of Guayule (Parthenium argentatum) under Cultivation, by W. B. MacCallum.

When a wild plant is domesticated and transferred from a natural state to the condition of intensive cultivation, new forms make their appearance sooner or later. The cause of this occurrence of new varieties is not altogether clear. They may be forms already existing unobserved in nature, or they may be variations that would have occurred any way, and not necessarily caused by the environment of cultivation. To what extent the direct influence of the conditions of domestication may induce permanent variations is not apparent; indeed, many exclude this altogether as a factor in the origin of new varieties. The absence of accurate record, however, and the obscurity of time have left a very inadequate knowledge of the behavior of plants in this respect when first brought into cultivation. In *Parthenium argentatum* we have the unique case of a plant, not only brought suddenly into domestication from a wild state, but from extremely arid and desert conditions to an environment of intensive cultivation in a region of exceptionally favorable climatic conditions, grown in very large numbers, and every step a matter of most accurate record.

In the dry and rather stunted condition in which the desert plants usually exist it was difficult to determine with certainty more than two or three unquestioned varietal forms, although many differences, especially in regard to size and habit, were discernible that did not seem to be altogether environmental. Grown under culture, however, with uniformity of soil and other conditions, the differences of environment are largely eliminated and the recognition of strictly varietal differences becomes easier. Over 100 different forms, quite distinct from one another, have been isolated. Between some the differences are slight,

though distinct and clear-cut, but in most cases the differences are so pronounced and conspicuous as to be recognizable at considerable distances in the field. The differences exist in practically every character of the plant, such as size, color, arrangement of the flowers, time of flowering; shape, size, color, arrangement of leaves, general habit of the plant, as erect, diffuse, open, compact; ranging from tree-like erectness to procumbent. In size the differences are very remarkable, the extremes being as 25 to 1. In such characteristics as the secretion of oils, tannin, resin, etc., there are also striking differences—in some varieties one or more of these being present in a pronounced degree and in others almost entirely absent. Such a character as the winter condition of the leaves affords opportunity for conspicuous variations. The leaves ordinarily are quite persistent through the winter, giving the plant every appearance of an evergreen, but some forms tend to drop many of their leaves in the winter and become partially deciduous, and the extreme is reached in at least one case, which is absolutely deciduous.

As the plants are pollinated by minute insects crawling about in the flowers, it was naturally expected that cross-pollination would be of frequent occurrence and that many of the different forms would prove to be of hybrid origin and would follow the usual custom of hybrids in the segregation of characters. This complete permanency, however, of all the varieties argues against the idea of their hybrid origin. Assuming them to be mutants, we would expect them to breed true, as they do. Pure cultures of practically all the varieties are being maintained and any mutations that may occur will be observed. So far none have been recorded. It is quite improbable that the plant has reached the end of its capacity to originate permanent variations, and although all of the hundred or more varieties now existing originated previous to their being brought under cultivation, we can look with some confidence to at least some continuation of this process under observation.

All attempts at cross-pollination between different varieties have thus far given no results. That they are, at least in a large measure, sterile to one another is evident. To what extent hybrids are possible, and between what varieties, and their behavior, are questions yet to be determined.

The Rôle of the Factors in a Desert Complex in Evolution Processes in Leptinotarsa, by W. L. Tower.

During the present year, substantial structures (of reinforced concrete and cypress) have replaced the temporary ones hitherto used. In addition to the new arrangements for the actual experiments, a complete system of water-pipes supplies each cage, saving much time and wastage of water and in other respects contributing to the efficiency

and economy in the operations. In addition, a small but commodious record building has been erected and equipped, and also concrete cellars with heavy double covers, provided for the installation of the recording instruments, protecting them from the weather and reducing the instrumental error as well as the dangers of damage to the instruments. In all respects the plant, as now constructed, gives greater security and is far more efficient than the previous arrangements.

The winter of 1914–15 showed another possible mode of action of the desert complex upon its inhabitants, for the cold, wet conditions inflicted (in all of the cultures) a heavy loss, roughly estimated at the present time at about 90 per cent. This loss was uniformly of the extremes in all the hibernating populations, so that the different extreme types isolated (for tests of this year) in the last generation of 1914 were eliminated. This is in accord with many other experiences at the Desert Laboratory during the course of these investigations, and I have had the same results in nature in experiments in the tropics in Mexico and at Chicago. It thus seems that the eliminating action in a population, together with its relation to the mean or modal group, is rather constant, regardless of the nature of the factors of elimination. In this process there is an element of conservation rather than one of diversification. In all of these experiences in elimination I find that a freshly isolated divergent group is, rather uniformly, entirely eliminated, while one that has been isolated for two or more generations is not eliminated, as it has apparently undergone some population adjustment and established a mean that is able to meet the diverse eliminating factors to which it is subjected. Interesting data have been collected, in the course of the experiences at the Desert Laboratory, upon which it will be possible to base an experimental analysis of this problem. There can be no reasonable doubt that these relations are of the highest importance in the establishment of species and groups in nature and in their distribution and ecological relations. In spite of the heavy eliminations, no losses of any moment were sustained in the cultures.

In 1912, 1913, and 1914 report was made upon the alteration of the water relations in *L. decemlineata*. The tests which were made in the winter of 1914–15 show almost the same results as hitherto; the stock was returned to Chicago for hibernation. Tests to determine whether this alteration is reversible have shown, as the result of breeding the Tucson lines at Chicago for two generations before hibernation, that a small percentage may be able to pass the northern winter (0.1 to 0.5 per cent), but in subsequent seasons these have not been able to develop a race that has the cold-resisting capacity of the original stock. Apparently, the alteration is slightly reversible, but more slowly, and possibly not to the original condition. Tests of the inheritance of this alteration in 1914–15 gave the same results found in previous years.

These cultures of *L. decemlineata*, reared continuously through many generations under desert conditions, are beginning to show other changes in color, in pattern, in sculpture, and possibly in reactions or behavior. Many show slight alterations; some tested in the laboratory at Chicago are permanent, others are not so permanent, and the entire series gives one the idea of being subjected to some disturbing processes that have not yet gone far enough to manifest themselves in pronounced changes or to indicate just what is to be the outcome. Present indications are that in these series of cultures we are observing the effects of the continuous pressure of the medium upon the race. I hope that these lines can be continued long enough to give some experimental basis for opinion upon this problem, and unless some accident happens the present equipment renders the prospects for this much greater than in previous years.

The mutating stem stocks noted in previous reports, although largely reduced by the winter's elimination, so that the surviving populations were all close to the mode of the group, have continued to show the production of mutants in each generation, one that appeared being a further alteration of one that had previously been obtained. This series of cultures and its mutant products have now been sufficiently tested with regard to their production in nature at Tucson and in the laboratory at Chicago to determine the type of behavior and its method of production. Six more of the mutants have been subjected to genetic testing and analysis during the past year at Chicago, so that the constitution of several of them is now partly known. None of these have so far shown any new gametic agents, the mutants in every instance being due to combinations of agents that entered into the original stem stock from the parental species. Although no new gametic agents have been discovered, and may not be produced by this process, it is obviously one that, operating in nature, would produce no end of heterogeneity and give an opportunity for the establishment of independent new specific groups.

Within the last three years a new inheritable type of modification has appeared, which concerns fundamental alterations in the stripes upon the elytra, of a kind and extent not known in any of the original species. This series of changes, which now are found in nearly all of the mutating stem stocks, arises slowly by small variations and in many respects seems to be due more to environment than to the mutating process which the stocks show, although it is not possible in this series to distinguish clearly the causes.

Cultures of these elytral modifications tested in the laboratory at Chicago show complete genetic stability, a high degree of dominance over the normal, and (what is more interesting) a sort of orthogenetic progression, simpler conditions being followed even in pure lines by more and more complicated conditions of pattern arrangement.

Some rather complex pattern types have been extracted, and these are in some cultures already giving more complex conditions, so that there is no means of knowing how far the process will go. The tests being made of these alterations at Chicago are under standard and uniform conditions, in which at the least the usual environmental action is eliminated, but in spite of this the apparent orthogenetic progression continues by what appear to be some series of internal operations that are gradually working themselves out, giving stable pure lines during the process. Collectively the series shows a wide array of new conditions due, as far as present evidence goes, to the introduction of some new gametic factors and the gradual production of the possible combinations between these and the existing factors.

No new cultures have been introduced at Tucson during the year, owing to the derangement of the investigation by the building operations and the poor transportation to and from the tropical areas whence many of the desired introductions come. The political conditions in Mexico also seriously hinder the investigations, it being quite impossible to obtain from the southern part of Mexico materials much needed.

The general oversight and care of the experiments has been continued through the year by Mr. J. G. Sinclair.

Relationships and Distribution of the Cactaceæ, by N. L. Britton and J. N. Rose.

At the time the report on the progress of this investigation was written last summer, Dr. Rose was engaged in exploring the cactus deserts of western South America, one-half of the expense of this expedition being borne by the New York Botanical Garden. He returned in November 1914, having secured notes, photographs, specimens, and living plants of most of the cacti which inhabit Peru, Bolivia, and Chile; his field studies and subsequent museum work have demonstrated the existence in these regions of several hitherto unrecognized genera of Cactaceæ and a number of undescribed species. The collections made by Dr. Rose were extensive, and their study and description occupied much of the time of both research associates during the winter and early spring, but substantial progress was also made in writing descriptions of other cacti, preparatory to the publication of the monograph of the family. Many additional drawings and paintings have also been secured.

Dr. Britton gave part of the month of March 1915 to further studies of the cactus region of Porto Rico, visiting most of the area inhabited by these plants along the southern coast of that island and obtaining additional information on geographic distribution.

In last year's report reference was made to the desirability of exploring also the cactus regions of eastern South America, and through a continuation of cooperation with the New York Botanical Garden Dr. Rose proceeded in May to eastern Brazil, making Bahia his first base of

operations; he next carried the work into Argentina, and returned in October, having made an immense collection of living plants and prepared specimens, together with much systematized information.

Dr. Rose was much impressed with the similarity of the cactus flora of the vicinity of Bahia to that of the West Indies. He remarks in a letter to Dr. Britton:

"I have been greatly surprised at the close relationship between the flora of Bahia and that of the West Indies, for there has been a general understanding that the two were quite distinct. This is strikingly true in the cacti and there is good reason to believe that it is equally true in other families. This relationship is much closer to the West Indies than to the west coast of South America. The species of the two regions are quite distinct, but many of the genera are the same."

We had already known that the cacti of the Venezuelan coast and of the Dutch Islands near that coast had some affinity with West Indian types, as is also indicated by the present incomplete knowledge of other groups of plants, and this knowledge, taken together with the observations of Dr. Rose about Bahia, lead us to believe that an exhaustive study of the flora of the whole northern coast of South America with relation to West Indian affinities would be a very valuable contribution to geographic botany.

As regards further field work, before closing the present cactus investigation, it is desirable that Ecuador and Venezuela be visited, that some further studies be made in Arizona and New Mexico, and that another expedition be made to Southern Brazil and Argentina. Cordially proffered cooperation by Professor J. J. Thornber, of the University of Arizona, is gratefully acknowledged, as also the contribution of valuable specimens by Mr. W. H. Long.

The Immediate Effects of the Injection of Reagents into the Ovary in Torenia fournieri, by Francis E. Lloyd.

Torenia possesses an embryo-sac, one end of which, containing the egg-apparatus, protrudes much beyond the mouth of the ovule. On general grounds this genus therefore appeared to afford material peculiarly suitable for ovarial treatments. It has eventuated, however, that so far as methylene blue is concerned, the progress of events is as in *Scrophularia* (see previous report). The study has thrown some additional light on the mechanism of the embryo-sac, especially of the egg-apparatus. The structure of the ovule is essentially that of *Scrophularia*. It has, however, a longer funicle, and the exostome is directed toward the placenta. The protuberant end of the embryo-sac lies roughly parallel to the funicle and its conical free end lies normally against a placental pollen-tube "conductive tissue" of papillate cells with strongly mucilaginous free walls. The embryo-sac is therefore free only in a morphological sense and in practice it is difficult to reach

the egg-apparatus directly by means of watery solutions lying within the locule. Furthermore, the embryo-sac is invested by a cuticle which is discontinuous only for a small area at the apex, at which point the gelatinous ends of the synergidæ protrude. Only at this point might watery solutions find ready entrance but for the above-mentioned conditions. When the ovules are dissected out and bathed with tap-water, the synergidæ absorb enough water frequently to burst inwardly with respect to the embryo-sac, the vacuole disappearing. It may also happen that the bursting results in extrusion of the synergidæ from the apex of the embryo-sac. The delicacy of adjustment of the sexual mechanism thus indicated is further demonstrated by the fact that the cells of the egg-apparatus and endosperm are plasmolyzed by a solution of potassium nitrate slightly more concentrated than 0.1/N. In plasmolysis, the protoplasmic membrane, proper to the endosperm, lying against the egg-apparatus is withdrawn therefrom, while the vacuoles disappear by contraction from the egg and synergidæ. It is this behavior which shows that the entrance of the water into the embryo-sac is through the uncuticularized apex. The difficulty of applying a watery solution to the unprotected embryo-sac is apparent.

It is, however, possible to reach the egg, as in *Scrophularia*, by injecting the ovary. The course of movement of methylene blue lies through the funicle and chalaza, and accumulation occurs in the tapetum, a layer of cells investing the antipodal moiety of the embryo-sac. From this region the reagent passes along the embryo-sac to the egg-apparatus. That this behavior is perfectly definite is shown by the fact that it is identical with that in orthotropous ovules, of which a few are usually found in each ovary.

The course of the pollen-tube is as follows: Passing along the mucilage cells of the placenta, it attacks the embryo-sac at the uncuticularized apex, passing down between the tips of the synergidæ to reach to the egg-cell. The egg meanwhile loses its vacuolated structure, its whole volume being occupied, the protoplasm having the appearance of that of the pollen-grain. It is doubtful if fertilization involves the destruction of one or both synergidæ by the pollen-tube.

Development and Persistence of the Fruit in the Cactaceæ, by Duncan S. Johnson.

Work on this problem has been pursued during the current year at Johns Hopkins University, and from April to September at Tucson and Carmel. As in the past, chief attention has been devoted to the origin, the anatomy, and the fate of the persistent fruits of *Opuntia fulgida*. Studies have also been made of the persistence and proliferation of the fruits of other species of *Opuntia* and to the development and distribution of the flowers of the giant cactus.

Seeds of *Opuntia fulgida* were germinated at Baltimore to seedlings a centimeter long. The germination of these seeds has not hitherto been reported, so far as is known. It evidently occurs but rarely in the field and was accomplished in the laboratory only after part of the seed coat had been cut or filed away. Careful search among the fruiting plants of *O. fulgida* at Tucson in April failed to reveal any plantlets that could be shown to have arisen either from seeds or from fallen fruits. All the young plants seen had evidently come from the areolæ of fallen vegetative joints. A search in September 1915 led to the discovery of a dozen rooted fruits which evidently had sprouted during the summer rains. Thus, though fallen fruits readily give rise to new plants in the greenhouse, they apparently do not do this frequently in the field. By following the fruit development of *O. fulgida* through the whole summer it was found that four, or possibly more, generations of fruits may be added to one of its fruit chains in a single growing-season. The primary flower of the season, developed in spring from a persistent fruit of the preceding year, may form secondary flowers from its own areolæ. These secondary flowers open several weeks after the primary ones and may themselves give rise to tertiary flowers, and the latter in turn often form flowers of the fourth generation for the season in August. In other cases only one or two fruits, or sometimes none, are added to a chain during a whole season. Hence it is evident that the longest chains seen, made up of 12 or 14 fruits, may be formed in three or four years or may take eight or ten.

A study of the behavior of the fruits of other species of *Opuntia* growing about Tucson and at Chico, California, showed that there are several species in which the fruits may persist for one or two years attached to the parent plant, though none forms such large fruit-clusters as *O. fulgida*. Thus in *O. spinosior*, *O. arbuscula*, and in certain plants of *O. versicolor*, at Tucson, many single, persistent normal fruits and occasionally chains of two or three were found in April. In several of the flat-jointed opuntias about Tucson and in most plants of *O. versicolor* no attached fruits were found in April 1915 except abnormal ones that harbored the pupæ of the cactus fly, *Asphondylia opuntiæ*. Most of these galls had the form of hypertrophied, unopened flower-buds. In these the red of the petals still persisted and, aside from being twice the normal size, they appeared as if just ready to open. They do not open, however, but in May the pupa-cases protrude through the wall of the fruit, the flies escape, and by June most of the galls have withered and dropped. A few only of the less hypertrophied buds formed flower-buds from their areolæ in 1915. In only two or three instances had a persistent gall given rise to a vegetative joint. When these galls of *O. versciolor* were planted beside the fruits of *O. fulgida* on soil in the greenhouse, they did not, like the latter, give rise to vegetative shoots, but withered and decayed.

The development of vegetative shoots from an attached fruit is as rare in *Opuntia fulgida* as in *O. versicolor*, only two cases having been seen in hundreds of plants examined. In *Opuntia arbuscula*, however, the lower of the attached fruits of certain plants regularly give rise to condensed vegetative shoots of several internodes each. When these fruits are put on damp soil the condensed shoots push out to initiate new plants. Attempts to artificially produce this vegetative proliferation of the areolæ of attached fruits of *Opuntia fulgida*, by removing all but three of the fruits of a cluster of 150, failed. In all the experimental plants thus far examined the few fruits left gave rise to flowers only, just as the fruits of the undisturbed clusters do.

The flowers of *Carnegiea gigantea* show certain irregularities in distribution and rate of development. These irregularities were studied by the aid of a compass in scores of crowns in the field and were accurately plotted for a number of typical crowns taken into the laboratory. The flowers were found to be either far more numerous on the east side of the stem, or, if more equally distributed, the flowers of the east side are more advanced in development. This one-sided growth is, perhaps, dependent on the higher average temperature of the east side of the thick stem, due to the fact that this side is not only first warmed by the sun in the morning, but also retains its temperature till late in the afternoon because of the relatively high temperature of the air from mid-day till sundown.

DEPARTMENT OF ECONOMICS AND SOCIOLOGY.*

HENRY W. FARNAM, CHAIRMAN.

The European war, which has affected unfavorably so many interests in our country, has been, on the whole, a benefit to this department of the Carnegie Institution of Washington; for the writer, instead of spending last winter in Berlin, as was his expectation a little over a year ago, came back to this country in the autumn of 1914 and has devoted most of his attention since that time to work upon the history of social legislation in the United States. He has also given considerable time to editorial work in connection with other divisions. Thus he has examined critically the manuscript of Professor Johnson's "History of Domestic and Foreign Commerce of the United States" and during the summer has read the proof of this book. He has also read the manuscript of Dr. Clark's "History of Manufactures in the United States," and made suggestions for preparing it for the press. He has supervised the revision of the history of transportation, and he has been in consultation with Mr. Parker regarding the first draft of his history of mining. While the writer was not formally appointed editor of the series, it seemed to him that the responsibility rested upon him, as chairman of the board, to harmonize and bring into unity the different parts, inasmuch as he is the only member of the board who is familiar with the work of each one of the collaborators. In not a few cases it seemed desirable to make suggestions regarding both the form and the substance of the manuscripts which passed through his hands and to settle a large number of typographical questions which arose as soon as the first manuscript was accepted and its printing authorized by the Executive Committee. In this work he has had the assistance of Professor Johnson and Dr. Clark, who have by vote of the collaborators been associated with him as an editorial committee, and to whom he is much indebted for useful suggestions and advice.

In reviewing the work of the several divisions the writer is glad to report that one of them has actually completed its task. Professor Johnson's "History of Domestic and Foreign Commerce of the United States," having been handed in last spring, was accepted by the Executive Committee, and will soon be published in two volumes, aggregating about 800 pages, with several maps. In the preparation of these volumes Professor Johnson was assisted by Dr. T. W. Van Metre, Assistant Professor G. G. Huebner, and Dr. D. S. Hanchett.

Dr. Clark's "History of Manufactures in the United States, 1606 to 1860," which has also been accepted, is nearly ready for the press.

The "History of Transportation in the United States to 1850," written under the direction of Professor Meyer, was handed in over a

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year ago. It contains much valuable material, but the writer was not satisfied that it was in proper form for printing. It has accordingly been subjected during the past year to a thorough revision, in order to improve the diction and to secure greater accuracy and uniformity in the footnotes. The former work has been in charge of Dr. John Cummings, the latter, of Mrs. A. A. Best, whose experience as Dr. Clark's assistant gave her especial qualifications for the work.

Mr. Parker, who has now given up his office in the United States Geological Survey in order to take the position of director of the Anthracite Bureau of Information of the anthracite mining companies of Pennsylvania, prepared the first draft of his history of mining last winter. The writer has examined this manuscript of over 500 pages and discussed it with the editorial committee, and Mr. Parker expects to put further work upon it this winter. Most of the material has been gathered, but the original plan seemed likely to give the history a disproportionate compass, and a large part of Mr. Parker's available time has been devoted to solving the problems of condensation. Mr. Parker reports the following regarding the work of his assistants: The chapter on the history of iron-ore mining, by Professor C. K. Leith, has been completed since the last report; Professor R. J. Holden, assistant to Professor Leith, has subjected it to an editorial revision, and it is now being re-typewritten. Dr. F. B. Laney has been unable to finish his chapter on the history of the quarrying industry, and it is now being completed by Mr. G. F. Loughlin, of the United States Geological Survey. Mr. Samuel Sanford, of the United States Bureau of Mines, has been assisting in the editorial work of the division.

Professor Commons's study of the labor movement is completed in substance, and is now undergoing a careful revision in order to prepare it for the press. The process has been a slow one on account of the magnitude of the work. Professor Commons has had as assistants Dr. Helen L. Sumner, Dr. John B. Andrews, Selig Perlman, E. B. Mittelman, and David J. Saposs.

The writer has made progress on his history of social legislation, and that part of it which is now prepared for the press amounts to about half of what the finished work is expected to be. A good many topics require more personal research than was at first expected, and the time which he had hoped to give to it during the summer was much curtailed by the editorial demands mentioned above.

In the division of agriculture Professor Henry C. Taylor's history of agricultural production from 1840 to 1860 is nearly completed. It is a detailed study of the subject from original sources, but as it had not yet been received by President Butterfield, when he made his report, no recommendation can be made with regard to publication. The work of Dr. L. C. Gray on the history of the plantation from 1840 to 1860 is nearing completion, and the author has returned from

Saskatchewan to Madison in order to finish it under the immediate supervision of Professor Taylor. Progress on the other sections of the history of agriculture has been slow.

The treatment of the subject of population has been carefully blocked out by Professor Willcox, and he has made substantial progress, but has been delayed during the year by a number of unforeseen circumstances, one of which is his election to the presidency of the American Economic Association. After the annual meeting of that society in December he hopes to have more time for the work of this department.

For the Division of State and Federal Finance, Professor Gardner reports that he has received a monograph by Professor E. T. Miller, of the University of Texas, on the financial history of Texas, and he has also received some chapters on the financial history of Virginia from Mr. Edgar Sydenstricker. No other monographs have been turned in or published. Professor Gardner has, however, during the year, employed as an assistant Mr. Henry R. Bowser, who has been engaged in arranging and classifying the notes and references to material which Professor Gardner has collected and of which he has many thousand. Mr. Bowser has also been studying the history of State finance on the basis of the studies already made. As there will be a great deal of original work which will have to be done in addition to the monographs in hand, Professor Gardner has during the summer employed Mr. Bowser and some students to work on State documents, of which the State Library at Providence has a large collection. Professor Gardner has given practically all of his own time during the summer to the work of the Department.

In the divisions of Money and Banking and of The Negro very little has been done during the past year on account of reasons personal to the heads of these divisions, as explained in earlier reports, while the whole treatment of the subject of industrial organization has been awaiting the completion of certain other divisions in order to avoid duplication.

In view of the fact that certain important sections of the "Contributions to American Economic History" are approaching completion, while others are well advanced, it again becomes desirable to raise the question of the future of the Department. Those divisions which are either finished, or so far advanced that we may reasonably look forward to their completion within a few years, cover the subjects Population, Manufactures, Mining, Transportation, Commerce, Labor, and Social Legislation. It will be noticed that these divisions form a fairly well-rounded group of closely related subjects. They cover what may be called, in general, primary economic subjects. Even if all of the remaining subjects should remain unfinished, the work of these six divisions would justify the title "Contributions to American Economic History," adopted for the work of the Department as a

whole. I, therefore, venture again to bring to the attention of the Trustees the question of the reorganization of the Department which was referred to in the reports for 1911, 1912, and 1913. The work thus far accomplished in the economic history of the United States has been done by a group of men working in most cases either without pecuniary compensation, or with a very small indemnity for such time as they have been able to take from their vacations or their leisure hours, actuated by the desire to put the work through and to present the results for the benefit of scholars. As one division after another is completed, the group of collaborators automatically shrinks. This method of work has proved to be economical, even if slow, and is perhaps the best that could have been adopted for the particular kind of study that we have been undertaking, but it is unsuitable for a permanent organization.

Miss A. R. Hasse reports as follows regarding the Index of State Documents:

"The New Jersey volume of 705 pages was issued during the year. The next volume, Pennsylvania, has been completed and is in press. The volume to follow Pennsylvania, South Carolina, is well under way. The Pennsylvania volume promises to be very bulky. The increased size is due to the exceptionally large number of documents included in the 'Collected Documents' and to the great quantity of railroad material."

The complete list of indices published (with the years in which they were issued) and in preparation now includes the following States:

California	1908	New Jersey	1915
Delaware	1910	New York	1907
Illinois	1909	Ohio	1912
Kentucky	1910	Rhode Island	1908
Maine	1907	Vermont	1907
Massachusetts	1908	Pennsylvania (in press).	
New Hampshire	1907	South Carolina (in preparation).	

I respectfully recommend that the Department be reorganized under a salaried head, and that it be given a sufficient income to carry on a consecutive series of studies on some of the lines outlined in a special report made in 1913.

In the meantime, the various divisions of our work in economic history which are well advanced can be carried on to completion with slight additions to the appropriation already made, and if, in the course of a few years, it turns out to be impossible to procure the completion of those divisions which are still in arrears, we shall yet have the satisfaction of turning out a well-rounded group of contributions to the economic history of the United States which will serve as a basis for future study and will, it is hoped, inspire other individuals or other organizations to fill in the gaps which we have been obliged to leave.

DEPARTMENT OF EMBRYOLOGY.*

FRANKLIN P. MALL, DIRECTOR.

During the past year, in addition to the completion of a number of researches which will be detailed in the following report, several events have occurred that signify progress in the organization and development of the general plan of our work in embryology. First of all should be mentioned the formal establishment of this work as a definite department of the Carnegie Institution of Washington, which was authorized in December 1914.

This has been followed by an increase in our permanent staff. Margaret R. Lewis was appointed collaborator on January 1. Mrs. Lewis's recent investigations have been in the domain of experimental cytology and her work constitutes an important factor in our plans for the development of the experimental side of embryology. Our cytological investigations will receive further support by the appointment of Professor Jules Duesberg as Research Associate. Professor Duesberg, who is well known in connection with his work on mitochondria, was professor of anatomy at Liège before the German occupation of Belgium. On account of the interruption of his work by the war he came to this country and since February 15 has continued his researches under the auspices of our Department.

Professor Evans resigned his position as Research Associate on June 1 in order to take up his duties as professor of anatomy in the University of California. His work, which was outlined in my previous report, has been continued, but unfortunately has not reached a conclusion. During the spring Professor Bartelmez, of the University of Chicago, came to Baltimore to work with Professor Evans on the anatomy of human embryos of about 2 mm. in length, and it is now planned to have Professor Bartelmez continue this work.

Sarah J. Phelps was appointed assistant to Dr. Streeter on the 1st of September 1914. Joseph Drane and Ethel S. Duffield were appointed technical assistants, the former on September 1, 1914, the latter on July 1, 1915.

Together with the increase in our staff, provision has been made for more adequate quarters. A new fire-proof building is now being erected by the Johns Hopkins University adjacent to our present location, one floor of which, consisting of 4,400 square feet, has been especially designed for our purposes.

The European war has seriously interfered with the work of Professor Keibel and has deprived him of all of his assistants, one of whom, Dr.

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von Alten, died during Easter week. However, during the summer Professor Keibel's duties as a teacher have not been heavy, and as Dr. von Lippman has been at Strassburg for the greater part of this time it has been possible for them to continue their scientific work. Professor Keibel, in collaboration with Dr. von Alten and Dr. Boeker, has been engaged in the study of the structure and development of the thymus gland, using for this purpose reptilian embryos collected by Dr. von Gossler in the Dutch East Indies. A preliminary report of Dr. von Alten's portion of the work, on the development of the branchial pockets in turtles, has been published. In *Chrysemis marginata* independent bodies develop from the fourth and fifth branchial pockets, which subsequently unite with the supra-pericardial body, so that this body appears to arise from these branchial pockets. Partly for this reason von Alten concluded that the supra-pericardial body arises from a sixth branchial pocket, as is the case in teleosts and other animals. Furthermore, he has shown that in the turtle the first three branchial clefts give rise to organs—which fact is of importance, since various authors believe that the thymus arises from such organs. Since the death of Dr. von Alten the further study of this question has been carried on by Professor Keibel on his own material as well as upon specimens loaned by Professor Maximow of Petrograd. The work of von Lippman on the development of the urogenital system in man, although interrupted by the war, is nearing completion.

I have formally transferred to the Department of Embryology my collection of human embryos, which is the result of unceasing efforts during the past twenty-five years. This collection consists of nearly 2,000 specimens, many of which have been prepared in permanent serial sections. It is already unique both in magnitude and importance, but a vigorous effort is being made to increase it still further. It is now safely housed in fireproof rooms, together with the original data, drawings, photographs, and clinical records, which are second in importance only to the specimens themselves. Convenient classified lists and a card catalogue have been prepared in order to render all of this material easily available. Circulars addressed to physicians setting forth the needs of the department have been widely distributed and have called forth a hearty response from the medical profession. These circulars have also been referred to frequently in many medical journals in Asia as well as in this country. The Health Department of Baltimore and the State Board of Maryland have cooperated most generously by instructing all physicians in the State to send such specimens to our collection as could be obtained, and they have made special regulations to facilitate this work.

During the past year a number of memoirs have been submitted to the Carnegie Institution of Washington for publication. These are brought out under the title of "Contributions to Embryology."

The following papers have been published.

Publication No. 221:

No. 1. Mall, Franklin P. On the fate of the human embryo in tubal pregnancy.

Publication No. 222:

No. 2. Watt, James C. Description of young twin human embryos with 17-19 paired somites.

No. 3. Clark, Eliot R. An anomaly of the thoracic duct with a bearing on the embryology of the lymphatic system.

No. 4. Meyer, A. W. Fields, graphs, and other data on fetal growth.

No. 5. Corner, George W. The corpus luteum of pregnancy as it is in swine.

No. 6. Essick, Charles R. Transitory cavities in the corpus striatum of the human embryos.

Publication No. 223:

No. 7. Sabin, Florence R. On the fate of the posterior cardinal veins and their relation to the development of the vena cava and azygos in the embryo pig.

No. 8. Duesberg, Jules. Recherches cytologiques sur la fécondation des ascidiens et sur leur développement.

No. 9. Shipley, Paul G., and George B. Wislocki. The histology of the poison-glands of *Bufo agua* and its bearing upon the formation of epinephrin within the glands.

The plan is to publish in the Contributions those papers from the Department or in relation to the Department which on account of their extent and the character of their illustrations can not be published in technical journals.

The first paper of this series is by myself, on the fate of the human ovum in tubal pregnancy. The material for this study includes 146 specimens which have been collected by about 100 physicians in various parts of the United States and in Asia during the past eighteen years. This work lagged until it received support from the Carnegie Institution of Washington, and I am pleased to present it as the first paper appearing in the Contributions from the newly established Department of Embryology. The scope of the work is not only embryological, but also etiological—*i. e.*, the cause of tubal pregnancy.

The specimens are in most cases accompanied by data bearing upon the cause of tubal pregnancy, and a review of these data shows quite definitely that this condition is associated with inflammatory changes which must have preceded the lodgment of the ovum in the uterine tube. Under normal conditions the tube is lined with a layer of ciliated epithelium, which constantly works in the direction of the uterus and therefore creates in the tube a stream of fluid from the ovaries to the uterus. The fertilized ovum is caught up by this stream, and if the conditions are normal is carried into the uterus. Any change which delays the ovum in its progress will favor tubal pregnancy. It is well known that abnormal diverticula or duplicate tubes may be the cause of tubal pregnancy. Numerous isolated cases have been described in which a blind tube or large diverticulum contained the implanted ovum. In rare instances, after an operation on one of the tubes, an ovum is subsequently found in its blind inner end, whereas the corpus luteum is seen in the ovary on the opposite side, showing that the ovum crossed

the body and entered the operated tube instead of passing out through the free passage existing between the ovary and the uterus on its original side. However, these anomalies are rare and can not be viewed as the rule in cases of tubal pregnancy. Much more commonly associated with tubal pregnancy is a chronic inflammation followed by adhesions and kinking of the tube. This has been repeatedly observed, but it is difficult to establish etiological association between adhesions on the outside of the tube with the arrest of an ovum within its lumen.

In case the ovum becomes well implanted within the middle of the tube and ruptures into the broad ligament, conditions are brought about which favor the development of a normal embryo. Rupture on the free side of the tube throws the embryo into the peritoneal cavity and therefore usually terminates its life. The same is true when the implantation takes place near the uterus. Here the tube distends with difficulty. The ovum burrows into its thick wall and usually passes straight through into the peritoneal cavity.

Whenever the degree of alteration in the tube wall is pronounced and is accompanied by marked infection, the ovum does not implant itself well and consequently the embryo does not develop normally, but becomes atrophic and degenerates. The more severe this process the more pronounced is the reaction upon the ovum; or in case it begins to develop normally, excessive hemorrhage around the ovum detaches the chorion from the tube and strangulates the embryo within. It dies immediately, showing no tendency to grow in an irregular fashion. Later it disintegrates.

Pathological ova without embryos are very frequently encountered. They have been found in 59 per cent of our selected cases, while only 2.7 per cent of specimens obtained from the uterus fall under this heading. But, as Werth also admits, the figures in both groups are probably much too small, as no doubt many of the earlier specimens were lost or overlooked. We have no adequate data regarding the number of ova which disintegrate early, but the study of comparative embryology warrants the conclusion that many young ova degenerate and disintegrate.

Pathological embryos in the tube, as well as those in the uterus, no doubt give rise to merosomatous monsters which are not of hereditary character. Studies relating to this subject are still under way.

In addition to the work on pathological embryology, various studies have been published which will be described in the following order: cytology, development of the nervous system, development of the blood-vessels, development of the lymphatics.

Our cytological studies include further investigations on mitochondria by E. V. Cowdry, W. H. and M. R. Lewis, and J. Duesberg. The behavior of cells in the presence of vital stains and the character of the macrophage cell have been investigated by H. M. Evans, K. J. Scott, W. B. Martin, and C. R. Essick; M. R. Lewis has grown muscle-cells in tissue cultures and has studied the rhythmical contraction of such

cells; G. W. Corner has studied the development and finer histology of the corpus luteum.

The study of mitochondria has been the object of considerable attention in the department during the year. E. V. Cowdry has continued his researches on the mitochondria of the spinal ganglion cells. He finds them throughout the whole series of vertebrates and states that they are characterized by the constancy of their morphology, distribution, amount, and micro-chemical properties. There is a reciprocal relation between the amount of mitochondria and lipoid granules in the spinal ganglion cells. Dr. Cowdry believes that they are connected with the metabolic activity of the nerve-cells. Observations on the Nissl bodies show that these bodies are not visible in the unstained cells. In the fixed or stained cells they appear either as definite bodies or, especially in small cells, as a diffuse amorphous deposit. Cowdry records some observations which apparently support the idea that the Nissl bodies are not preformed in the living cell, but result from the coagulation of this amorphous substance.

The same author has turned his attention to the vital staining of mitochondria with janus green and diethyl safranin in human blood-cells. Mitochondria can be demonstrated by these vital stains in the lymphocytes, large lymphocytes, finely granular leucocytes, and occasionally in the coarsely granular leucocytes and platelets of normal adult human blood. They are totally absent in the non-nucleated red blood-cells of the adult. These two observations are in accord with the current conceptions of the physiological significance of mitochondria and show that mitochondria are to some exent indicators of cellular activity, for they are present in the active stages of cytomorphosis (lymphocytes, large lymphocytes, and finely granular leucocytes), and absent in the terminal or later stages (non-nucleated red blood-cells). Cowdry further points out that the term "non-granular leucocyte" is in reality a misnomer, for the so-called non-granular leucocytes all contain mitochondria.

Cowdry's conclusion regarding the absence of mitochondria in the red blood-cell of the normal adult is confirmed by the researches of P. G. Shipley; but Shipley shows further that the young non-nucleated erythrocytes contain mitochondria. The presence of mitochondria is a character of the youth of these cells, and this character may be useful in clinical researches in diseases which increase the activity of the hematopoietic organs.

M. R. and W. H. Lewis have found the tissue cultures of chicken embryos an excellent material for the study of the mitochondria in the living cell. They find that the mitochondria are almost never at rest, but are continually changing their position and also their shape. The changes in shape are truly remarkable, not only in the great variety of forms, but also in the rapidity with which the change is made from one

form to another. A single mitochondrium may bend back and forth with a somewhat undulatory movement, or thicken at one end and thin out at the other, with an appearance almost like that of pulsation, repeating this process many times. Again, a single mitochondrium sometimes twists and turns rapidly, as though attached at one end, like the lashing of a flagellum, then suddenly moves off to another position in the cytoplasm as though some tension had been released. Corresponding to the forms observed in the stained preparations, we find in the living cells that granules can be seen to fuse together into rods or chains, and these to elongate into threads, which in turn anastomose with each other and which may unite into a complicated network, and in turn may again break down into threads, rods, loops, and rings.

The work of M. R. and W. H. Lewis includes also most interesting experimental researches on the influence of chemical agents, heat, and hypotonic and hypertonic solutions on the mitochondria, which open a large field to further investigation. Regarding the connection of the mitochondria with other granules, as well as with cytoplasmic differentiation, these authors are rather skeptical. They believe that the mitochondria are in all probability bodies connected with the metabolic activity of the cell.

Studying the fertilization of *Ciona intestinalis*, J. Duesberg reaches the conclusion that the whole spermatozoon, head, tail, and mitochondrial body, enters the egg, but he is unable to determine the fate of the mitochondrial body in the egg.

The egg itself shows at its vegetative pole an accumulation of mitochondria. At the expense of this part of the egg are formed the muscle-cells, which throughout the cleavage are characterized by their considerable amount of mitochondria. The other cells of the embryo show also constant cytological differences. The entoderm and the chorda cells are filled with yolk granules and contain only very few mitochondria; in the ectoderm cells, mitochondria and yolk are about equal in quantity, while the neural plate cells contain a few more mitochondria than do the ectoderm cells. Finally, the appearance of the mesenchyme cells is very striking, owing to the fact that they contain very few granules of any kind.

The conclusion is that the differences shown by the various kinds of cells of the embryo are not due to the presence of different organ-forming substances, but to a regular and peculiar distribution between them of the formed elements contained in the egg.

The work of Professor H. M. Evans on the macrophages is closely connected with his previous studies on the behavior of the different cells of the organism towards the vital dyes (see former report). His conclusions are that the macrophages may be defined as those mono-nuclear cells, wherever they may be, lining vascular channels, resident in the connective tissues or entirely free, whose protoplasm constitutes a

physical system characterized above all by its response to finely particulate matter. In the case of particles of ordinary microscopic dimensions, this response (phagocytosis) is a behavior shared equally with the polymorphonuclear elements of the blood. But towards the very much finer ultramicroscopic particles the macrophages react in a practically specific way, "drinking them in," as it were, and storing them either as free coagula in their protoplasm or as the inhabitants of watery vacuoles, where they oscillate in ceaseless Brownian movement.

From his definition of the macrophages he proceeds to a consideration of their function in the body. He regards them as storing substances of importance to the organism which are in the colloidal state. There is little doubt that this action in this capacity obeys the principle of a physiological balance, for only in cases in which the local or general content in the substance is very high do they load with it, and they no doubt liberate their content to an impoverished fluid. For the latter phenomenon an analogy is found in the occurrence of decolorization of animals stained by these dyes, where the liberation of their dye content by the macrophages stands in direct relation again with the physical character of the dye solution, highly dispersed ones escaping rapidly, highly colloidal ones adhering stubbornly to their depots.

In all of these processes connected with tissue destruction the macrophages house the complex chemical bodies set free, and thus become the great cells finally so apparent to the eye. There is a growing recognition of the fact that many of these bodies are in colloidal systems like the dyes.

Another contribution to the knowledge of macrophages is furnished by Dr. C. R. Essick's work on the transitory cavities of the corpus striatum of the human embryo. The reference concerning the exact morphology of the cavities is given elsewhere. Essick found in these cavities a great number of peculiar cells which exist also in other parts of the embryo and which show the following characters: they are very large, much larger than the erythrocytes; they often build pseudopodes; their protoplasm is finely granular and vacuolar; their most important character is the presence of inclusions, especially of erythrocytes, which can be found in the different phases of intracellular digestion. This last feature shows that these cells really belong to the class of macrophages; they are extravascular phagocytes.

Miss K. J. Scott's researches on vitally stained cells of the subcutaneous tissue of the mouse lead her to the conclusion that isamine or trypan blue is not associated with some preformed element of the living cells, but is simply stored in the cytoplasm—as Evans and Schulemann thought—by a sort of ultramicroscopic phagocytosis. In this special case Miss Scott shows, contradicting Tschaschin, that the elements colored *in vivo* in the cells of the subcutaneous tissue by the isamine blue are not mitochondria.

In an article by W. B. Martin on neutral stains as applied to the granules of the pancreatic islet cells, a method is set forth for staining the granules in the cells of the islets of Langerhans by which the A and B cells can be differentiated from each other and from the cells of the parenchyma as well. This method is founded on Bensley's neutral gentian method, but makes use of a number of new neutral stains. The neutral dyes are obtained by combining various acid dyes of the azo series with certain of the basic triphenylmethane dyes. A list of these neutral compounds is given, with a brief description of the properties and the relative merits of each as a granular stain. It is shown that at least two of these dyes—*e. g.*, neutral azofuchsin is obtained by combined hexaethylpararosaniline with azofuchsin, and neutral ethylviolet resulting from the combination of orange G with the same basic stains—are distinctly superior to neutral gentian as a differential granular stain. This superiority lies in the fact that they are both very intense stains, giving a brilliant color contrast in the section and resisting well the action of differentiating agents.

Some very important observations have been made by M. R. Lewis on the growth of muscle-cells. Tissue cultures were made from pieces of the limb-buds of 4, 5, 6, 7, 8, 9, and 10 day chick embryos explanted in Locke's solution and the abundant growth of skeletal muscle tissue and connective tissue which arose from the explanted piece was kept in a healthy condition—*i. e.*, with numerous mitotic divisions, often as one mitotic figure in every four or five resting cells—by bathing the growth each day with Locke's solution, to which had been added 0.5 per cent dextrose and either a trace of yolk or a small quantity of chicken bouillon.

Occasionally among the numerous muscle fibers of such a growth one may be seen to contract rhythmically for varying periods of time. The time interval of the rhythmical contraction is different for each fiber or myoblast. Some contract rapidly—120 times a minute; others only once in 200 seconds, and some not oftener than once in from 1 to 5 minutes.

An attempt was made to stimulate the muscle-fiber of the growth to contract rhythmically, as was done by Howell with the terrapin heart, by Loeb with the frog skeletal muscle, Stiles with the smooth muscle of the frog, and Lingle with the ventricle of the terrapin heart. Although the results were not sufficiently definite to permit of any conclusion in regard to which one of the salts stimulates the muscle to contract, nevertheless the observations show that by some thus far unknown change, either in the tissue itself or in the surrounding medium, the myoblast and also the muscle-fibers of the skeletal muscle of the chick embryo may be stimulated to contract rhythmically when entirely free from nerve influence and subject only to the stimuli which emanate from their environment. This property is inherited from cell to cell,

even when generations of cells have taken place in a simple Locke's solution.

Dr. G. W. Corner has investigated the differences between the corpora lutea at the different periods of their evolution and has attempted to obtain criteria for the determination of the age of these bodies. In the corpus luteum of the sow he has described three kinds of cells—the lutein cells and the additional cells of the corpus luteum, types 1 and 2. His study shows, in the different ages, the variations of these two latter types of cells and the cytological changes of the lutein cells, in their canalicular apparatus, in their granules (especially in the quantity of fat granules), in the colorability of the nucleus, and in the relative quantity of exoplasm and endoplasm. Certain stages of the evolution of the corpus luteum show also an increase in the connective tissue. All these changes occur with perfect constancy, and Corner has thus been enabled to establish a regular series. The corpus luteum of pregnancy differs from the corpus luteum of ovulation in the greater regularity of its structure and its smaller content of fat. He shows further that in the sow during pregnancy no other Graafian follicle becomes mature and that the external migration of the egg is a frequent and normal phenomenon.

Certain features in the development of the nervous system have been the subject of investigation during the year. Among these are included a study of the sensory nerve-endings in muscle, experimental studies on the membranous labyrinth, experimental degenerations of the spinal cord, a volumetric study of the development of the parts of the brain, and a histological study of the temporary cavities that are found in embryonic brain-tissue.

Mr. A. C. Sutton has added to our literature the first complete description of the embryological history of the sensory nerve-endings in muscle and accompanies it by illustrations showing the principal stages in their development. The intricate structure of the full-grown neuromuscular spindles makes the study of their simpler forms particularly valuable. Mr. Sutton's investigations were carried out on the extrinsic eye-muscles of embryo pigs in which the sensory nerves and their endings were studied by staining *intra vitam* with methylene blue. The earliest stage in which he was able to distinguish them was in embryos 12 mm. long. From this point they were followed up to pigs 200 mm. long, where they practically have their adult form.

He finds that the axones (embryo 12 mm.) grow out from the cells of the sensory ganglia and terminate in the premuscle mass in bulbous ends from which delicate fibrils extend a little further and lie loosely among the rounded myoblasts, to which they subsequently become attached by the formation of a neuro-fibrillar net. With the development of the myoblast into the adult muscle fiber this net becomes more and more complex, and at the same time an intermediary structure is

developed between the neuro-fibrillar net and the muscle-fibers forming transverse plaques which form previous to and lie within the sarcolemma and apparently are comparable to the receptive substances of Langley found in motor nerve-endings. In the later stages these plaques become obscured by the thickening of the fibrillar net. Finally, in pigs 200 mm. long the entire spindle-mass becomes inclosed in a connective-tissue sheath, such a spindle consisting of as many as 15 fibers. It is interesting to note that no degenerating muscle-fiber was found by this investigator where the muscle was provided with a nerve-fiber.

In previous experimental studies on the amphibian ear-vesicle Dr. Streeter has investigated the factors concerned in the determination of the posture of the ear-vesicle and the resultant membranous labyrinth. It was shown that where the ear-vesicle is transplanted to another specimen and intentionally placed in an abnormal posture there is a subsequent spontaneous correction to normal posture and that the resulting labyrinth bears normal relations to its environment. The next step was to estimate the time at which this spontaneous rotation of the ear-vesicle occurs. During the past year this has been fairly well determined, so that the histological conditions under which the phenomenon occurs can now be studied.

Dr. Gilbert Horrax produced experimental degeneration of the ventral and dorsal spino-cerebellar tracts by a lateral incision in the thoracic region at the level of the sixth thoracic vertebra of the spinal cord of the dog. Examination of the material prepared by the Marchi method from three such experiments showed that there was an ascending degeneration on both sides of the cord, though more marked on the operated side. The fibers could be traced from the dorsal tract to the caudal half of the vermis and the adjacent medial portion of the lateral hemispheres of the cerebellum; from the ventral tract the fibers could be traced to the cephalic half of the vermis. Loss of muscle sense and tone in both hind legs followed the operation, from which there was complete recovery in 3 weeks. These results confirm the work of other recent workers who have approached the problem in different ways.

A volumetric study of the development of the parts of the brain is being made by Dr. Streeter and his co-workers. The object in view is to obtain a history of the volume growth of the individual parts of the brain, with the idea that a knowledge of their volume priority would indicate in a general way the functional priority of these parts. By the method of wax-plate reconstructions, enlarged models of the embryo brains are made which can be separated into their chief component parts. Since in a given model the wax is of a uniform composition the relation by volume and by weight of the different parts can be determined both as to each other and to the brain as a whole. The study of one stage—the brain in a fetus of 156 mm. crown-rump measurement—has been completed and published by Professor F. C. Dockeray. Studies of other stages are well under way.

It has been found by Dr. C. R. Essick that, in the human embryo, in the substance of the corpus striatum there is a separation of the nervous tissues, causing the formation of two bilaterally symmetrical transitory cavities—cavum mediale corporis striati and cavum lateralis corporis striati. These cavities make their appearance in embryos about 15 mm. long and disappear as the growth exceeds 20 mm. The cavities vary in shape and may be either simple or multiple, but they are always found in a constant position. An interesting feature is the presence within the cavities of a large number of peculiar ameboid phagocytic cells which otherwise are foreign to nervous tissue. They resemble morphologically the macrophages of the adult and the Hofbauer cells of the embryonic chorion. The cavities are evidently of functional significance, and the author advances the hypothesis that they result from an accumulation of cerebro-spinal fluid and that they disappear as soon as adequate drainage of their contents into the meningeal spaces becomes established.

Studies on different phases in the development of blood-vessels have been published during the year by G. L. Streeter, E. R. Clark, and F. R. Sabin.

Dr. Streeter has made an embryological study of the venous sinuses of the dura mater in the human embryo. This is in continuation of the work published by Professor Mall in 1905. The present study is based on human embryos belonging to the Department of Embryology and in it is traced the development of the veins of the head in embryos from 4 mm. long upward, through successive stages to the adult conditions. In addition to the value of the morphological details that are brought out, it is of especial interest on account of its bearing on the broader principles involved in the establishment of vascular drainage. The particular group of veins studied affords striking examples of changes and adjustments in drainage channels which are consequent upon the alterations in the form and condition of the particular area drained. The marked change in the form of the brain, and particularly the prolonged relative growth of the cerebral hemispheres, render necessary a continuous series of alterations in the veins that extend throughout the greater part of fetal life.

To a great extent this adjustment is accomplished by the migration of the principal blood-channels. This migration occurs in two ways. There is the passive change in position or direction of the endothelial tube itself, due to mechanical causes arising from alterations in its environment. On the other hand, a vein may change its position by forming or adopting a new endothelial channel, at the same time relinquishing its original endothelial channel. The plexiform arrangement of the veins in the region of the tentorium is especially favorable for this procedure, and in this region this type of alteration is repeatedly illustrated. In other words, under migration of veins one can distinguish

between "passive migration," in which there is a change in position due to some flexion or traction on the vein wall itself, and "spontaneous migration," in which there is a change in position of the blood-stream only, whereby by circumfluent anastomosis the blood-stream develops a new channel in the adjacent loops of the plexus, whereupon the previously used loop correspondingly dwindles.

In the adjustment of the drainage of the head there also occur instances of the formation of new replacement channels with consequent obliteration of old ones—which process, however, can not be classed as spontaneous migration. It is a change in position, but the change is an abrupt one. The new channel turns off at once into an entirely new direction. Moreover, the new channel lacks the morphological characteristics of the old one. As in spontaneous migration, this change is accomplished by circumfluent anastomosis. An example of this type of adjustment is seen in the otic region. Owing to the growth of the cochlea and the structures of the middle ear the course of the primary head-vein, ventro-lateral to the otic capsule, becomes an unfavorable one and this portion of the primary head-vein becomes obliterated. Adjustment is made for this in two ways. First, a channel is established dorsal to the otic capsule through which the middle dural plexus is drained caudally into the posterior dural plexus. Secondly, the anterior dural plexus, which originally drained into the primary head-vein, fuses with the middle dural plexus and drains caudally through this and through the new channel dorsal to the otic capsule. This makes a complete trunk for the drainage of the head, which is throughout its course dorsal to the primary head-vein as far caudalward as the jugular foramen, where it is continuous with the jugular vein. This trunk becomes the transverse sinus and can not be regarded as a migrated primary head-vein, though to a large extent it replaces the latter.

As a final variety of adjustment in the veins of the head there is the formation of entirely new veins, which become necessary for the drainage of structures that are late in making their appearance. It is found that in their development the veins of the two sides of the head are asymmetrical and that the sagittal plexus in embryos from 20 mm. upward, in about 90 per cent of the embryos examined, drains predominantly toward the right side.

Professor Clark has published studies on the growth of blood-vessels in the tail of the tadpole. By direct observations he has been able to add confirmatory evidence to the Aeby-Thoma conception of the adaptive capillary formation of blood-vessels. The arterioles and venules develop from an indifferent capillary plexus, any capillary of which may become incorporated in the advancing arteriole or venule, depending upon whether it is favorably or unfavorably placed as regards the more peripherally situated capillary mesh. In the embryonic chick he suc-

ceeded in removing the large primitive vein on one side of the neck and found that it was soon replaced by a new one—showing that mechanical conditions favor the development of a large vein at this place and that it is not simply the result of inheritance.

An investigation has been completed by Professor Sabin concerning the fate of the posterior cardinal veins and their relation to the development of the inferior vena cava and the azygos veins. Owing to the complicated changes in the embryonic organs of this region, their venous drainage undergoes intricate alterations which have been confusing to investigators. There have consequently appeared in the literature obscure and conflicting descriptions of the development of these veins. By perfected injection methods Dr. Sabin has been able to establish the essential details of this interesting process. Chief interest in this study concerns the posterior cardinal vein. This is found to be primarily a vein for the drainage of the Wolffian body which determines its morphology and fate. As the Wolffian body disappears the posterior cardinal vein also completely disappears. It is true, it anastomoses temporarily with the veins that are to develop into the azygos system and the inferior vena cava, but it does not play a permanent part in their actual formation, as has been generally believed.

The circulation of the Wolffian body is completely treated in this study. It is of primitive type, in that the veins do not accompany the arteries. The arteries enter along the hilum of the organ and are distributed to the glomeruli as afferent and efferent vessels, after which they break up into capillary plexuses which surround the tubules. The blood is collected from these plexuses into three longitudinal surface veins, all of which at first drain into the duct of Cuvier, and which constitute important members of the cardinal system; they are the posterior cardinal vein, the mesial cardinal vein (subcardinal), and the ventral vein. These are abundantly connected by transverse anastomosing veins. Subsequently the right mesial cardinal vein establishes a communication with the liver, after which the posterior two-thirds of the Wolffian bodies drains through this channel—that is to say, through the inferior vena cava. The anterior one-third of each Wolffian body continues to drain into the duct of Cuvier through the posterior cardinal and ventral veins. As the Wolffian body disappears the posterior cardinal and ventral veins also entirely disappear, and there is left only the modified mesial cardinal vein which has become incorporated in the inferior vena cava.

The inferior vena cava is primarily a vein which drains the Wolffian bodies, being formed from the omphalo-mesenteric vein within the liver and from the right mesial cardinal vein below the liver, which anastomoses with the left mesial cardinal through the median mesonephritic vein. At first the veins of the leg and tail drain into this system through the Wolffian body, but as the tail disappears new chan-

nels are formed in the prevertebral venous plexus, which thus becomes a part of the inferior vena cava. The inferior vena cava may therefore be said to have a ventral segment and a dorsal or post-renal segment, the ventral segment coming from the omphalo-mesenteric and mesial cardinal veins and the dorsal segment from the prevertebral plexus.

The azygos and hemiazygos veins are new longitudinal veins which develop as an adjustment of the drainage which is due to the disappearance of the Wolffian body and the changes in the adjacent body-wall. They are, however, entirely distinct from the posterior cardinal veins, which disappear with the Wolffian body. The azygos veins develop entirely in the prevertebral plexus. They, however, anastomose freely with the cardinal system and in a way replace it. For, as the posterior cardinal veins diminish in size the azygos veins grow larger, assuming a drainage of the spinal veins with their tributaries. Thus at a certain period the two are of about the same size and can then be seen draining into the duct of Cuvier as separate veins, the azygos maintaining a more dorsal position than the posterior cardinal. Subsequently, as the posterior cardinal continues to dwindle, its point of termination migrates from the duct of Cuvier downward along the now relatively large azygos vein, into which it drains until it finally disappears.

In Dr. Sabin's paper there is included an historical survey of injection methods, with a critical description of the more recent technique. Further work concerning the early development of the blood-vessels of the chick has been under way during the past year, a preliminary report of which was read at the St. Louis meeting of the American Association of Anatomists.

In our last report it was stated that the early lymphatics in the chick which are destined to form the posterior lymph heart arise from the adjacent veins and immediately fill with blood which backs into them. Within a few days the embryonic lymph heart thus formed begins to pulsate. These first movements are described in a study by E. L. Clark and E. R. Clark.

These authors find that the pulsation of the lymph heart first appears in embryos of six or seven days (19 to 22 mm.) and that, at this earliest stage, the beating of the lymph heart is intimately connected with the periodic muscular movements of the embryo. Lymph-heart contract tions accompany the periodic spasms, but never occur in the interim between the body movements. Each beat is invariably accompanied by a contraction of the tail. When the body movements are paralyzed by chloretone the lymph-heart pulsations also cease. In successive later stages they find a gradual increase in the independence of the beating lymph heart. First, the pulsations become dissociated from the tail contraction, although still occurring only during the periods of body movements. Then there is a series of stages in which the lymph

heart contracts more and more frequently during the period of rest, although still beating a number of times during each spasm. When chlorotone is added a larger number of single pulsations occur independently at irregular intervals. At these stages the lymph heart is capable of entirely independent function, but is influenced in its rhythm by the periodic spasms of body movements.

Finally a stage is reached in which the lymph-heart pulsations are uninfluenced in any way by the body movements. During all of these stages mechanical stimuli, such as pressure over the surface with a fine needle or direct puncture of the myotomes, fail to influence the body movements. Although the lymph heart does not respond to pressure over the surface, it always contracts when its wall is actually pierced. At the stage in which the lymph heart is not yet independent such a puncture causes tail contractions together with the pulsations, while at later stages it stimulates the lymph heart alone.

This work has now been extended by E. L. Clark to include a study of the first lymph flow in the superficial lymphatics in chicks from five to nine days old. After the lymphatic plexus in the tail of the chick forms the posterior lymph heart it gradually extends anteriorly over the body to meet a like extension which arises in the neck. These two networks unite over the hip. At this time the lymphatics remain filled with blood which leaks in from the veins. As the flow of lymph begins they empty themselves of blood, first through the neck lymphatics and then through those which flow into the posterior lymph heart. Many experiments were made to test this flow by injecting india ink into the lymphatics of the living chick and observing it under favorable conditions. Only a preliminary account of this study has been published.

Professor E. R. Clark has also published an account of the general anatomy of the lymphatic system, as well as of a unique variation of the thoracic duct in man, which appears as No. 3 of the Contributions to Embryology. In this specimen the region normally occupied by the thoracic duct was obstructed and therefore the lymph flow from the lower part of the body followed the primitive lymphatics under the skin to the axilla and established there a "thoracic duct" outside of the thorax, which remained throughout life. A knowledge of the early lymphatics and the circulation through them makes the anomaly intelligible.

A preliminary account of Dr. R. S. Cunningham's study on the development of the lymphatics in the lung of the pig has been published and a final report is being prepared for press.

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. Davenport, Director.

Among the principal advances of the year have been the extension of the series showing the evolution of the chromosome complex of *Drosophila* and allied flies (perhaps the strongest purely cytological argument yet presented for the individuality of the chromosomes); the lack of dependence of the vigor of certain strains of parthenogenetic *Cladocera* upon the recurrence of sexual reproduction; the discovery that in different strains of *Lychnis* there is a difference in the dominance of one and the same trait, hermaphroditism (including maleness); the demonstration that in certain plant hybrids the characters whose determiners are derived from both parental germ-plasms develop more promptly than those whose determiners come from only one side of the house; the demonstration of a triple factorial basis of the foliage color of *Lychnis*, and of multiple determiners in the reduction of the number of bristles in *Drosophila;* the working out of a theory of a pair of factors (and their absence) that is capable of explaining the hereditary basis of temperament; the demonstration that the symptoms of certain diseases (Huntington's chorea, pellagra) are determined by several hereditary factors—are, indeed, "syndromes"; the demonstration that hereditary brittle-bone (or osteopsathyrosis) is due to a dominant factor; the production of a strain of beans with double the usual number of cotyledons and "first leaves" of the seedling; the preparation for the press of one volume of the unpublished scientific work of the late Professor Whitman.

STAFF.

The work of this Department during the present year has been carried on by seven resident investigators and various associates and assistants. The Director has, besides his other duties, put most of his time on the analysis of the data of human inheritance, assisted by Miss Mary T. Scudder. Dr. George H. Shull has used plant material for his studies in heredity and has been assisted part of the time by Mr. B. C. Helmick. Dr. J. A. Harris also has paid particular attention to the inheritance of abnormalities in beans, with the assistance of the Misses Lockwood and Margaret and Lillie Gavin.

Mr. Charles W. Metz is making studies on the subject of the mechanism of heredity and has been temporarily assisted by Mr. H. H. Plough. Dr. Oscar Riddle has worked on the chemical distinctions that lie at the basis of sex, with the assistance of Miss Adelaide Spohn and, later, of Mr. O. R. Clutter.

*Situated at Cold Spring Harbor, Long Island, New York.

The subject of inducing mutations is being pursued by Dr. E. C. MacDowell, both by the use of alcohol and by constant extreme atmospheric conditions applied to rats. He has been assisted in part by Mr. J. W. Gowen. Dr. A. M. Banta is also studying the problem of the possible genetic influence of absence of light, such as is experienced by cave animals. He has been assisted by Mr. D. C. Warren.

We are concerned with the processes by which species become adjusted to the environment. Drs. Harris, Banta, and MacDowell are studying the results and limits of the process of selection.

We do not lose sight of the fact that heredity is the control or direction of ontogeny and as opportunity permits we wish to continue and extend the studies that Dr. R. A. Gortner and others have initiated here on the biochemical changes accompanying the development of special traits. Drs. Harris and Riddle are doing something in this field, assisted especially by Mr. John V. Lawrence.

The staff has sustained a great loss in the resignation of Dr. George H. Shull, who has accepted a call to the chair of botany and genetics at Princeton University. Dr. Shull has been a member of the staff from the organization of the Station—over eleven years. By his persistence, thoroughness, clear insight, and single-mindedness in the pursuit of his investigations he quickly attained the first rank of botanical students of genetics. It is early to state which of the discoveries made by Shull at this station will come to be regarded as most important. His colleagues here have been much impressed with his demonstration of the isolation of the inferior biotypes in maize through inbreeding and the demonstration of the multiplicity of biotypes in a species regarded at one time as unique in its genus—the shepherd's purse. It is probable that a hundred biotypes (elementary species) could be isolated from the shepherd's purse. If this can be done with so constant a form as shepherd's purse, how vast must be the number of biotypes in notoriously variable species like golden-rod and ragweed. The idea of biotypes which Shull so greatly developed is bound to revolutionize, in time, our conceptions of zoological and botanical species and, most important of all, man himself. Shull also attacked with courage numerous difficulties that arose in his work—such as abnormal ratios, the amazing intricacies of *Oenothera* hybrids, and the sex ratios in a partially hermaphrodite plant (*Lychnis*). While some of these difficulties of ratios were cleared up, and yielded generalizations as to aberrancy due to duplicate, plural, and linked genes, others are still awaiting interpretation.

The vacancy created by Dr. Shull's resignation has been filled by the appointment of Professor Albert F. Blakeslee, of Storrs (Connecticut) Agricultural College. Dr. Blakeslee is no stranger to the Department; he carried on experiments here from October 1912 to June 1913, on mutation and sex in mucors, and, with Dr. Gortner, discovered the

Rhizopus toxin, upon which experiments are still being made with the assistance of the U. S. Department of Agriculture.

Dr. Harris and Mr. Lawrence spent some time in Jamaica studying the osmotic pressure of vegetable saps. Mr. Metz spent the winter months (January 15 to April 15) in Cuba and a few days in Jamaica, collecting and attempting to hybridize the *Drosophila* and allied flies there. He brought back numerous species to breed at the laboratory. Also pinned material, eggs, and notes on eggs, larvæ, pupæ, breeding habits, etc., were procured. Cuba proved to be unusually rich in *Drosophila*. Dr. A. M. Banta has spent the usual amount of time in exploring caves for animals to replenish our stock.

REPORTS ON INVESTIGATIONS IN PROGRESS.

The topics upon which work has been done in this Department during the past year may be classified as follows: (1) the germ-plasm and its modification; (2) the control of sex; (3) the inheritance of germinal peculiarities, especially those relating to sex; (4) the processes of forming species in nature and artificially; (5) general physiological topics.

THE GERM-PLASM AND ITS MODIFICATION.

More and more clear does it become that evolutionary changes are initiated in the germ-plasm—the chromosomes and adnexa. It therefore becomes of the first importance (*a*) to study the structure of the germ-plasm and the morphological differences in the chromosomes associated with differences in the soma; (*b*) to try to modify directly the composition and product of the germ-plasm.

MORPHOLOGICAL EVOLUTION OF THE GERM-PLASM.

This phase of our work is being carried out by Mr. Metz, who is using in his studies the genus *Drosophila* and the closely related genera of *Chymomyza*, *Scaptomyza*, and *Cladochæta*. Over 30 related species were thus examined cytologically. In these species 10 or 11 different types of chromosome complexes have been revealed; and, most important of all, these types are all closely related morphologically and can be derived, hypothetically, from an unspecialized central type by simple modifications in two or three directions. Thus, Mr. Metz has greatly extended the results of his studies that were briefly described in the Year Book for 1914 (p. 129). The analysis of these various types of chromosome groups and the task of relating them to one another has been rendered more difficult because of the interesting and complicated relations of the pair of sex-chromosomes. In some species the sex-chromosomes appear to be alike in both sexes (*i. e.*, X and Y are equal in size), while in other species that have the same type of chromosome group, X and Y are obviously dimorphic. This study appears to be the first in which the chromosome group has been analyzed in a large

number of related species and in which it has been possible to trace an evolution of morphological type. After this demonstration it will be impossible to deny the "individuality of the chromosomes." Obviously it will be of great importance to compare the inheritance of traits of which the determiners are carried in these dissimilar but closely related germ-plasms.

Mr. Metz further reports:

"In addition to the *Drosophila* work, the study of the phenomena of chromosome pairing and their significance has been followed up extensively. This has involved the cytological study of at least 60 or 70 species of flies representing various families of the order (including the Drosophilidæ). The essential features of chromosome behavior have been found to agree in all, and to point definitely to the conclusion that in all of them the chromosomes are permanent, qualitatively different, individuals; and, further, that the two members of each pair of chromosomes are *homologous maternal and paternal elements which remain associated with one another by reason of their qualitative similarity.* To my mind this latter forms one of the strongest cytological supports of the chromosome theory of heredity, if the evidence for it is conclusive, as I believe it to be. The report of this study is now nearly completed and will soon be ready for publication.

"In connection with the above study many interesting facts have been observed with regard to the sex-chromosomes, and the general relation between chromosome groups in the different families studied. It is astonishing what a variety of conditions has been found as regards shape, size, and number of chromosomes, presence or absence of chromatoid bodies, and other chromatic structures, etc., in these various groups of flies. There has been no opportunity to work these features out in detail, but there is material on hand for numerous valuable studies.

"One question upon which this material throws light has received definite attention, however—namely, that of the maturation phenomena. Very little is known about this question in the Diptera, yet it is one of especial importance in connection with current theories of chromosome behavior, *e. g.*, the "chiasmatype hypothesis," etc. Recently a supply of good material has been secured from the Asilidæ (robber flies), which are most favorable for studying maturation phenomena. This will be worked up and published as soon as possible, but it will require many detailed and careful drawings, in addition to observational study, and just now more immediate work occupies all available resources.

"At present, especial attention is being paid to the study of oogenesis in *Drosophila ampelophila* and to the work of determining the sex-chromosome relations in the males of that species, because of their bearing upon genetic data. Nothing very definite has resulted from this so far, however, although a quantity of material has been studied. The problem is one of especial difficulty as well as especial interest.

"Throughout the year the principal problem attacked has been that of hybridizing species of *Drosophila* possessing different chromosome groups. A large amount of time has been devoted to this, but without success. The experiments have now come to the stage in which it will be necessary either to perfect a method for artificially fertilizing eggs of one species with sperm of another or else to keep on getting additional species from localities hitherto not worked until some are secured which will hybridize. Either of these methods would give extremely important results if successful, but the latter would

lead, of course, to more far-reaching results by making breeding experiments possible. I shall continue to regard this problem as the most important one upon which to work during the coming year."

EXPERIMENTAL MODIFICATION OF THE GERM-PLASM.

This, which may be said to be the loftiest aim of the experimental evolutionist, has been so rarely achieved that all reported successes in this direction are received with critical skepticism. We are now provided with means for carrying out experiments on this difficult topic. In the Year Book for 1914 (p. 121) is mentioned the work, begun by Dr. G. C. Bassett, of inducing changes in the germ-plasm of rats by subjecting them to the action of alcohol vapor. This work is now in the charge of Dr. MacDowell, who reports as follows:

"Besides having a theoretical scientific interest, this problem has immediate sociological importance. It is frequently asserted that, in man, alcoholism in the parents results in their children having less than normal mentality. In order to prove this, much has been said and done. There are countless complexities which largely veil a clear solution of such a problem when man is considered directly. Since the problem depends largely on a pyschological analysis, it may be that, by employing the psychologists' indirect method of studying lower animals first, the essential relationships may be more accurately secured. If one could understand the mental methods of a lower or more primitive organism, those of the higher type might be mastered more easily. For other reasons than this is the use of a more simple form advantageous: the germ-plasm to be treated, as well as that of the controls, can be more easily selected in the first instance and bred in subsequent generations, the individuals to be compared can be maintained under like conditions, and the experimental treatment of all animals in the same group can be uniform.

"Since the white rat is a very satisfactory subject for behavior studies, this animal has been used. Since the beginning of this year the parental generation has been raised. Half of the rats were made to inhale alcohol fumes, for 90 minutes a day, following Stockard's method; the rest were saved as controls. The alcoholization was made daily for at least 100 days before mating, and then continued, in the case of the females, till immediately preceding the birth of her young. For every mating of alcoholics there was a mating of normal males and females from the same litters. The offspring from these two sets of rats have all been trained to enter a puzzle-box of a type planned by Watson and modified by Bassett. The comparison between the rats of normal and of alcoholic percentage has been made on the basis of the time required to gain access to the puzzle-box. The sooner a rat learns the trick, the higher his ability is rated. The training of each rat lasts 96 days, during which time the number of seconds required to make each of 225 successful trials is recorded. The number of rats included in this training is 145. Since the training of all these rats is not quite completed, no final statement of the results of this work can be made.

"Whereas the above method gives a fairly accurate comparison of the abilities to form a habit, it can not be claimed to measure the general intelligence of the rats. In order to secure data of a higher mental activity than that supposedly involved in solving the puzzle-box problem, a method has been adopted that was planned by Yerkes and called by him the multiple-choice method. As adapted for rats, the apparatus consists of a row of nine compartments with front and back doors. The rats are trained by punitive con-

finement (by closing the front door) when a compartment is wrongly chosen and by reward of food (which is revealed by raising the back door) when the right compartment is entered. The right compartment is never the same one in successive trials, but always bears a certain relation to the other open front doors. There may be some question as to whether a rat can have such an idea as the first door to the right (this being the relation of the correct door in the first problem), yet it is easily seen that in mastering such a problem the activity of the rats offers considerable insight into their relative mental capacities. As far as possible, all the rats trained with the puzzle-box will be further used in this experiment on the effects of alcohol. An additional reason for employing the multiple-choice method is to provide a check on the results of the puzzle-box training. Agreement in the two sets of results would give a basis for generalizations; disagreement would leave doubt as to the validity of either method. The technique of training has been developed, and at present twenty rats are being tested for intelligence by this apparatus."

A second investigation that has been planned is on the effect of temperature and humidity upon the germ-plasm. To make this experiment possible an extensive air-conditioning apparatus was installed in the animal house by the Harry Bentz Engineering Company. A detailed description of it is given toward the end of this report. Dr. MacDowell assumed charge of the experiments planned for this apparatus. About 20 rats were raised from infancy under the various combinations of conditions afforded by the air-conditioning apparatus, viz, hot dry, hot moist, cold dry, and cold moist. From these animals 10 controlled matings were made. Just when the next generation appeared it became necessary, through lack of funds, to discontinue the operation of the refrigerating machine. It is highly desirable to resume the experiment, even though it is expensive.

THE SIGNIFICANCE AND CONTROL OF SEX.

While the view that a difference in the sex chromosomes is sufficient to account for differences in sex characters is widely accepted by biologists, yet evidence is accumulating that the chromosomal difference is merely one differential and that there are probably others. Dr. Riddle has continued to collect evidence that supports the conclusion that an important differential associated with sex is the storage metabolism of the egg (Year Book, No. 13, pp. 117–119). Riddle's work during the present year confirms and amplifies his earlier conclusions.

As is well known, certain entomostracans of the group Cladocera are ordinarily parthenogenetic and for long periods females only are produced. Recently Keilhack, after going over all of the evidence, concluded that, while *Simocephalus* may behave differently, all species of the genus *Daphnia* and many other species of Cladocera which he names can not reproduce parthenogenetically for as long a period as six months. Unfavorable conditions may, indeed, hasten sexual reproduction, but constant conditions can not postpone the production of

sexual forms. Practically all workers with Cladocera (except the genus *Simocephalus*, in one case) who have reached a conclusion on the matter are in accord with Keilhack's statement.

In Dr. Banta's laboratory, however, quite a different result has been gained. Two *Simocephalus* lines have been reared for three years, during which time reproduction has been solely by parthenogenesis for 123 generations, and, indeed, no males have appeared. Another species, a long-spined species of *Daphnia*, has been kept reproducing by parthenogenesis only for 87 generations. Lines of *Daphnia culex* have been carried for nearly four years, and in several lines for from 148 to 157 generations, solely by parthenogenesis and without the production of males. In all of these cases there is no sign of loss of vigor in the stock. Periods of depression have, indeed, occurred, but these have always been obviously due to poor food conditions. As a test for possibly reduced vigor, careful comparisons between the lines reproducing for nearly 150 generations parthenogenetically and "wild" lines recently brought under laboratory conditions have been made throughout a period of several months. Three bases of comparison were used: the size of the first brood a mother produces, the age at which the first brood is produced, and the interval between the production of the first and second broods. The results of comparison on each of these points show that the young mothers in lines which have long reproduced parthenogenetically produce as large first broods, produce them at as early an age, and produce a second brood as quickly, as the young mothers in "wild" lines recently brought in from natural ponds. Dr. Banta concludes that, since no diminution in vigor or need for sexual reproduction is apparent in the different species after 87, 124, and 157 generations, respectively, sexual reproduction and the sexual cycle in these Cladocera are probably not inherently necessary, but are consequences of certain special environmental conditions.

That such special conditions may induce the production of males has, indeed, been demonstrated for rotifers by Whitney; and observations made by Dr. Banta show the same thing in Cladocera. In the "long spine" *Daphnia* one gynandromorph and a few males in two successive generations in two strains appeared at a time when males of other species of Cladocera (*Daphnia pulex* and *Moina*) were extremely abundant in the pond from which were obtained the food and water in which these cultures were maintained. The fact that a few males appeared in two strains reared under laboratory conditions simultaneously with the appearance of numerous males of two other species living in the outdoor pond which furnished the culture water strongly suggests the environmental control of the production of males.

THE INHERITANCE OF GERMINAL PECULIARITIES.

SEX.

Studies in inheritance in sex in *Lychnis*, so long conducted by Dr. Shull, were continued by him. This year has to a large extent confirmed the anomalous results previously secured (Year Book No. 13, p. 119) without, however, giving a clue to their explanation. The narrow-leafed males have again produced in most crosses only male offspring, and one narrow-leafed hermaphrodite which was crossed with 31 different females has produced a total progeny of 1,287 hermaphrodites, 2 females, and 1 male. It appears, however, that not all narrow-leafed males are alike in regard to the proportion of males which they are capable of producing. Of 17 families from crosses in which narrow-leafed males were used, 10 consisted of 517 males and no females, 4 contained 160 males and 5 females, and 3 had 95 males and 41 females. In this last group the females were also all broad-leafed individuals. There has still been not a single narrow-leafed female, and the little dwarf female which was classed as a narrow-leafed female in 1913 has yielded only broad-leafed progenies when crossed with narrow-leafed males.

While hermaphrodites of *Lychnis* have usually yielded a mixture of hermaphrodites and females and less frequently males and females, Dr. Shull found in a white-flowered German strain of *Lychnis* (*Melandrium album* Garcke) a single hermaphrodite mutant which, in 1913, produced only female offspring in three different families for which it served as the male parent. In 1915 this result has been exactly duplicated in 8 progenies from a second hermaphrodite mutant which occurred in the German strain in 1913. These 8 families have included 187 females and not a single hermaphrodite nor male.

INHERITANCE RATIOS OF BURSA.

During the current year Dr. Shull has continued his prolonged experiments on the breeding of *Bursa* and has been able to show: (*a*) that there is no significant correlation between the number of seeds in the capsule and the ratio of *bursa-pastoris* to *heegeri* plants in the progenies produced from those seeds, thus indicating that if selective elimination is involved in the production of defective ratios such elimination is independent of the causes which affect the number of ovules which develop into seeds; (*b*) that the plants which are homozygous with respect to the long, sharp lobes characteristic of *tenuis* develop this character at an earlier age than do those which are heterozygous for this character; (*c*) that there is a rather strong correlation between the time of flowering and the extent of development of the leaf-characters in certain biotypes from western America, the lobation of the leaves being less well developed in precocious plants than in those which develop more tardily—the same fact was apparent in a similar, though not identical, biotype from Holland; (*d*) that there is a close agreement between the number of recessives and of homozygous

dominants, and, in harmony with his earlier discovery of a ratio approximating 1:4:1, have been the results of an extensive test of a family in which the recessives were in *excess* of expectation, for in this family there proved to be an *excess* of homozygous dominants also, so that the ratio of DD:DR:RR was approximately 1:1.7:1; (*e*) that there is a correlation between the date at which the plants begin to bloom and the number of dominant genes which they possess. In harmony with this general result, the *heegeri* individuals usually begin blooming, on the average, several days later than the *bursa-pastoris* individuals of the same family.

In tracing the geographic distribution of the duplicate capsule-determiners, the most important step has been the testing of 7 individuals growing in nature at Landau, Germany, where the original *B. heegeri* was discovered. Of these 7 individuals, 6 had both of the duplicate determiners, *C* and *D*, and the other had only a single determiner for the triangular capsule, and produced an F_2 ratio of about 4:1. This prevalence of duplicate determiners at Landau was a surprise to Dr. Shull, as he had thought it probable that a single determiner for the triangular capsule would be found *generally* in the *bursa-pastoris* from that place. The F_2 families from crosses between *B. heegeri* and a biotype of *B. bursa-pastoris* from Tucson, Arizona, gave ratios approaching 10:1. As this is directly between the expected ratios 3:1 and 15:1, only the F_3 will demonstrate with certainty to which of these ratios the 10:1 should be referred. In continuation of this geographic study, crosses have been made between *B. heegeri* and a number of biotypes of *Bursa* from various parts of Europe, Asia, and America, and seeds have been secured from as many new regions as possible. Cultures of *B. grandiflora*, *B. viguieri*, and *B. bursa-pastoris apetala* have also been grown and used in crosses with one another and with *B. heegeri*. In most cases these crosses seem to have been successful.

BRISTLE INHERITANCE IN THE VINEGAR FLY, DROSOPHILA.

Among the burning questions in genetics is the significance of characters that seem not to be discrete units but to show all grades. Such a character is skin color in man (Carnegie Inst. Wash. Pub. No. 195) and size of body in rabbits and poultry. Recent studies indicate that the apparent blends are due to the numerous factors involved in the character. Another contribution to this subject has been made by Dr. MacDowell, to whom the analysis of "Size Inheritance in Rabbits" is due (Carnegie Inst. Wash. Pub. No. 196). In *Drosophila* there are normally four bristles (2 rows of 2 bristles each) on the back of the thorax. In other cases there may be one pair, or 2, 3, or 4 pairs of *extra* bristles, or the extra bristles may be uneven in number. Dr. MacDowell's studies show that there is a Mendelian factor involved in the inheritance of extra bristles, and as *normal* dominates *extra* it is concluded that there is a dominant factor which restricts the number

of bristles to 4. Without having rigidly demonstrated the conclusion, Dr. MacDowell finds it probable that the variation in the number of extra bristles is due to the absence of one or more accessory restricting factors.

OTHER STRAINS OF DROSOPHILA.

To provide material for the cytological work a large number of cultures of *Drosophila* have to be maintained. Mr. Metz has carried at all times between 100 and 200 cultures and at times there have been double these numbers. In attempts to hybridize different species, scores of special cultures have been made up and carried on. Also, mutant races have been sought and bred in species having different chromosome groups.

Mr. Albert M. Brown, of Columbia University, spent about two months of the summer at the laboratory studying the linkage of characters in heredity in *Drosophila*. Mutants with eosin-colored eyes and miniature wings were mated to individuals of wild stock from France, Australia, Central America, Cuba, and several points within the United States, and the linkage of the above mutant characters was studied. Over 56,000 F_2 progeny were embraced in the data obtained.

FOLIAGE COLOR OF LYCHNIS.

The foliage color of *Lychnis* has been shown by Dr. Shull to depend upon the presence of several independently inheritable factors, *Z*, *N*, and *Y*. When *Z* is absent albinos appear. When *Z* is present, together with both *N* and *Y*, the plants are of the normal dark-green color usually seen in this species. *Z* and *N* without *Y* produce a light-green race which Dr. Shull calls *pallida*, and *Z* and *Y* without *N* produce a variable yellowish-green race, which has been named *chlorina*. These two light-green races produce (when crossed together) only dark-green offspring, which yield F_2 progenies when bred *inter se*, consisting of dark-green and light-green individuals in approximately the expected ratio 9:7. The last term of this ratio should include 3 *pallida* (*ZZNNyy*), 3 *chlorina* (*ZZnnYY*), and 1 "*subchlorina*" (*ZZnnyy*). It was not known until this year whether such a form as *subchlorina* could exist, and it was conceivable that the ratio of dark green to light green in the F_2 might be 9:6 instead of 9:7. The existence of the heretofore purely hypothetical *subchlorina* has been demonstrated by this year's cultures, as two individuals used in crosses in 1913 had the *subchlorina* constitution.

INHERITANCE IN ŒNOTHERA.

Investigation of the hybridization phenomena in the œnotheras has been continued by Dr. Shull, and many of the F_2 combinations which had not been grown hitherto have been added this year, so that most of the possible combinations of *Œnothera lamarckiana* and the

three cruciate species, *Œnothera cleistantha*, *atrovirens*, and *venosa* have now been grown. In many combinations the evidences of segregation are clear, but in almost no instance does this segregation result in apparently typical Mendelian groupings.

A complete series of reciprocal crosses between each of the above-mentioned species and a local *biennis*-like species (unnamed) has given results which parallel in an interesting manner the results secured in the F_1 families already reported. These studies have now been extended to include two new cruciate species, *Œnothera robinsonii* and *stenomeres*, and two broad-petaled species, *Œnothera oakesiana* and *Œnothera biennis* L.

Special attention has been given to putative Mendelian characters, such as nanism, brevistyly, pigmentation of rubricalyx, etc., with the hope of discovering to what extent these characteristics are actually distributed in typical Mendelian fashion. The inverse correlation between the red pigmentation of the buds and that of the stems has been fully confirmed in the hybrids between a form of *Oenothera rubricalyx* and *rubrinervis* and between the same form and *Oenothera lamarckiana*.

PITCHER-LEAFED ASH TREES.

This season has again added a few specimens of pitcher-leafed ash trees to those previously noted in the pedigree families. The ratios in these two families now stand 1.18:1 and 2.17:1 as compared with the expected ratios 1:1 and 3:1, the pitcher evidently depending upon the presence of a single Mendelian gene. The precocity of development of this character, together with the degree of development attained, are largely influenced by environmental factors. Most of the trees have been transplanted, 153 which had not shown pitchers during the first three seasons of growth being sent to an otherwise vacant space in the northeast corner of the Hill Field of the Station for Experimental Evolution, and 137 of those with pitchers being sent to 131 universities, colleges, botanical gardens, etc. Other institutions are to receive trees this fall.

The survey of the area on which pitcher-leafed ash trees occur in nature has been completed, and this area has been found to be about twice as large as had been supposed heretofore, but no trees of considerable size have been discovered outside of the previously known area. The area occupied by pitcher-bearing trees is about 400 meters in diameter. All the ash trees on this area, from 1 dm. in height to large trees, have been carefully examined for pitchers, with the result that 357 have been found with pitchers and 5,806 with only normal leaflets. Trees having a trunk-diameter of more than 15 cm. are limited to a very small area, about 400 square meters in extent.

HEREDITY IN MAN.

The Director has been primarily engaged in analyzing data afforded by the Eugenics Record Office. The following studies have been completed or are, at the present writing, about to be published.

(1) *Violent temper.*—An analysis of 66 family histories shows that the tendency to this reaction reappears in successive generations, rarely skipping a generation. In one history it is traced through 5 generations; in a large proportion of the histories it is traced through 3 consecutive generations. The few cases in which neither parent of an affected individual is reported to have the tendency to outbursts are explained by obvious insufficiency of the record. The fact that the tendency to outbursts of temper does not skip a generation indicates that it is a positive or dominant trait. That segregation of this tendency occurs is shown by the ratio of affected offspring in any fraternity to the total number of offspring whose emotional history is fully described. From the mating of an uncontrolled and a normal person expectation is that 50 per cent of the children will be uncontrolled. A summation of all such children gives a total of 106 affected among 219 sufficiently described, or close to the 50 per cent expected on the hypothesis that the tendency to outbursts of temper is a simple, positive trait.

(2) *Temperament.*—A later study involved a consideration of temperament in general, a subject which Galton discussed, inadequately, thirty years ago. It is generally recognized that temperament is hereditary, but there is great diversity of temperaments: some persons are prevailingly gay, others prevailingly somber, and still others pass through alternating cycles of elation and depression. The following hypothesis was tested and met the conditions very satisfactorily:

> "There is in the germ-plasm a factor *E* which induces the more or less periodic occurrence of an excited condition (or an exceptionally strong reactibility to exciting presentations) and its absence, *e*, which results in a calmness. There is also the factor *C* which makes for normal cheerfulness of mood, and its absence, *c*, which permits a more or less periodic depression. Moreover, the factors behave as though in different chromosomes, so that they are inherited independently of each other and may occur in any combination."

For the test of the hypothesis 89 carefully described family histories were available, and these afforded 147 matings in which the mated pair, their parents (usually), and certain of their offspring were sufficiently described for the purposes of the test. The test of the hypothesis is found in a comparison of the expected and actual distribution of temperaments in the children of each sort of mating. Of the 45 possible kinds of matings, 29 were realized. The relations of the sums of the observed to the sums of the expected distributions among the nine classes of temperaments is shown in the following table:

	Observed	Expected		Observed	Expected
Choleric-cheerful	36	41	Nervous-melancholic	63	72[illegible]
Choleric-phlegmatic	25	46	Calm-cheerful	77	51[illegible]
Choleric-melancholic	30	19	Calm-phlegmatic	79	97[illegible]
Nervous-cheerful	128	98	Calm-melancholic	46	49[illegible]
Nervous-phlegmatic	149	154[illegible]			

There are several reasons for not realizing a very close relation between observed and expected; but the chief one is that there are sometimes several "expected" results; and in these cases the most varied result was taken as the "expected." Nevertheless, the relation between the two series is fairly close, the greatest difference being an unexpected excess of choleric-melancholics and corresponding deficiency of choleric-phlegmatics; also an excess of calm-cheerful and deficiency of calm-phlegmatic. These discrepancies imply a rather slight error in the classification of the observed cases.

We conclude, then, from our own data that the hypothesis is confirmed. In addition, an examination of the literature reveals clear evidence that a difference in the inheritance of extreme hyperkinesis (a dominant) and extreme hypokinesis (a recessive) has unconsciously been observed. And the differences in the conclusions of Rosanoff and Orr[1] and of Rüdin[2] concerning the inheritance of manic-depressive insanity—one regarding it as recessive and the other regarding it as sometimes dominant—are easily explained on the ground of its complex hereditary nature.

Finally the study throws light upon the "springs of conduct." Just what we shall do, in any situation, is determined by numerous factors, but the general nature of our reactions, whether violent or repressed, is determined by the hereditary nature of our temperaments. The romantic and the classic type of reacting, the hyperkinetic and the hypokinetic, the radical and the conservative, the feebly inhibited and the strongly inhibited, constitute a dualism that runs through our whole population.

(3) *Nomadism.*—A study was made of the records of 100 families one or more members of which have shown a tendency to run away from home, families, and duties or to engage in a nomadic occupation. In these families, out of 186 nomadics only 15 are females. The hypothesis that best fits the facts is that nomadism is a sex-linked trait. There is no clear case of a nomadic daughter whose father is known to be non-nomadic; all daughters (4) of two nomadic parents are nomadic. The criterion that half of the daughters and half of the sons of nomad-bearing fraternities derived from nomadic fathers are nomadic is satisfied so far as sons go, but the number of nomadic daughters is less than expected (only 26 instead of 50 per cent are nomadic). In general, our histories show that nomadic fathers may have no nomadic sons, but there is no case of a nomadic mother of more than two children none of whom is nomadic. Thus the hypothesis is supported with the proviso that certain cultural conditions may have a repressive effect even in the absence of natural inhibitions.

[1]Rosanoff, A. J., and Florence Orr, A study of insanity in the light of the Mendelian theory. Amer. J. Insanity, 68, 221–261 (1911); also Eugenics Records Office Bull., No. 5.

[2]Rüdin, E., Einige Wege und Ziele der Familienforschung, mit Rücksicht auf die Psychiatrie, Zs. ges. Neurol. Psychiat., 7 (Hft. 5), 487–585 (1911).

(4) *Dent in forehead.*—A fragment of a family history of a depression in the median frontal region of the cranium led to a publication (*Journal of Heredity*, April 1915) in which it was pointed out that the trait was inherited as a dominant.

(5) *Huntington's chorea.*—This disease, usually regarded as a "neuropathic entity," is defined by the following traits: (1) persistent tremors of the head, appendages, and trunk; (2) the onset of such tremors in middle or late life; (3) the progressive nature of the tremors; and (4) progressive mental deterioration. These characters are frequently found together; is their association a necessary one?

A study of four family complexes in eastern Long Island, southwestern Connecticut, south-central Connecticut, and eastern Massachusetts which show nearly 1,000 cases of Huntington's chorea yields the remarkable result that practically all can be traced back to some half-dozen individuals, including three (probable) brothers who migrated to America during the seventeenth century. But numerous "biotypes" with specific and differential hereditary behavior have already appeared. Thus, there is a biotype in which the tremors are absent, but mental deterioration is present; a biotype in which the tremors are not accompanied by mental deterioration; a biotype in which the chorea does not progress; and a biotype in which the onset of the choreic movements is in early life. In general, the symptomatology of chronic chorea is dissimilar in different strains of families. The age of onset, the degree of muscular involvement, the extent of mental deterioration—all show family differences and enable us to recognize various species, or biotypes, of the disease. These biotypes are less striking than they would be were it not for the extensive hybridization that is taking place between biotypes in random human matings. The data for the study were collected by Elizabeth B. Muncey, M. D., of the Eugenics Record Office.

The method of inheritance of some of the elements of Huntington's chorea has been worked out. In general, the choreic movements never skip a generation and in other respects show themselves clearly to be a dominant trait. The mental disorder is usually of the hyperkinetic or manic type, and this also shows itself as a dominant. The age of onset *apparently* tends to diminish in successive generations, "law of anticipation," but this is partly, if not wholly, illusory and is due to the fact that in comparing the age of onset in grandfathers with that in grandchildren we are not comparing on the same basis, for the grandparents are a selected lot (selected on the basis of late onset—at least late enough for them to become parents), while grandchildren include those in whom the onset is so early in life that they will never marry. If instead of comparing the average age of onset in successive-generations, one compares the age of onset in a number of choreic parents, *their* parents, and their grandparents, then the evidence for anticipation vanishes. Eight such series give for average

age of onset of the propositus 35.5 years, parent 38.8, grandparents 36.9. In this series we can see no evidence of anticipation.

(6) *Pellagra.*—At the request of the Thompson-Fadden Pellagra Commission of New York, the Director of this Department undertook a critical examination of a large number of fragmentary family histories collected by the commission with the assistance of a trained field worker from the Eugenics Record Office. Since Lombroso declared that the diathesis of pellagra is hereditary, the attempt to find what factors were present, if any, seemed worth while. The evidence seemed to justify the conclusion that, whatever the immediate cause of pellagra, the course that it followed, the particular symptons that it showed, had a clear hereditary basis. Thus, in certain families mental symptoms were pronounced, in others absent; in some families the intestinal derangements were most striking, in others they were hardly present. While the skin usually shows areas of extreme inflammation in some families, the dermal symptoms were hardly to be noticed in others. The characteristic differences in families affords the best evidence of certain constitutional hereditary differences—which determine or control the specific symptoms of pellagra.

(7) *Osteopsathyrosis.*—A study was made of all available pedigrees of hereditary brittleness of bones. The conclusion is drawn that the trouble is indeed hereditary and that the factor which determines the imperfect, brittle development of long bones is a dominant one. This conclusion is based on the fact that, as Griffith pointed out some years ago, the inheritance is generally direct, *i. e.*, does not skip a generation, but appears in one parent and one of that parent's parents. Further evidence that the trait depends on a single dominant factor is found in the proportions of the fraternity who are affected. Out of a total of 150 offspring of an affected parent 83 or 55 per cent are affected—not far from the 50 per cent that was to be expected on hypothesis. The phenomena associated with fragility of bones are not always alike in different families. In some families the bones are broken before birth; in others only after the infant has grown into a child. Families differ in the degree of pressure necessary to breakage and in the bone most apt to be broken. The "classical symptoms" of osteopsathyrosis constitute a syndrome whose elements are separately inheritable.

(8) *Stature.*—An analysis of the inheritance of the elements of human stature has been undertaken. Several hundred pedigrees of total stature have been analyzed, but more extensive data of another kind are being collected and analyzed.

THE PROCESSES OF FORMING SPECIES IN NATURE AND ARTIFICIALLY.

BUILDING UP A RACE BY SELECTION OF FAVORABLE MUTANTS.

Since the general acceptance of the mutation theory and its corollary, that of absence of evolution through the selection of non-inheritable fluctuations, it has become important to test the application of these principles in the production of new species. Dr. Harris has for the

fourth generation selected the bean (*Phaseolus vulgaris*) with respect to seedling characters. For the most part he has not succeeded in isolating strains of definite type, but in a few cases this has proved possible.

"A strain in which the number of cotyledons and of primordial leaves is far larger than normal has this year been grown in many thousands of individuals. Normally the number both of cotyledons and of primordial leaves is two. The great increase and the high variability in the number of both is shown by the accompanying table, based on a sample of seedlings of the 1915 culture. It is to be noted that the highest frequency for both number of cotyledons and number of leaves is double that which normally occurs. A peculiarity of this line of plants is the abundance of ascidia, already studied in another form, the ash, at this Station by Dr. Shull. At least two other highly but not completely abnormal strains are also available. These differ greatly in their morphological characteristics, but require further study before they can be tersely characterized.

"Material progress in the isolation of strains in chlorophyll production has been made. Several types of plants have been secured from those producing no chlorophyll to those normal in this regard, but the propagation of such strains, except through normal plants, is very difficult. Enough has been done, however, to indicate the heritability of a number of types."

Number of cotyledons.	Number of leaves.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Totals.
2	..	1	6	3	2	1	1	..	.	.	..	..	..	..	14
3	1	13	44	59	47	21	13	7	4	3	1	..	..	.	213
4	4	34	80	127	100	72	32	24	13	9	5	..	..	1	501
5	..	..	4	5	9	8	2	4	..	3	1	1	..	..	37
6	..	..	..	1	2	..	2	1	..	..	..	..	..	..	6
7	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1
	5	48	134	195	160	102	51	36	17	15	7	1	..	1	772

SELECTION OF FLUCTUATING VARIATIONS.

It is still extremely profitable to study the limits of effective selection. The work of Castle might lead us to conclude that through selection practically any character might be gradually modified and—if the process was prolonged sufficiently—might be modified to almost any extent. Two extensive experiments that we are carrying on bear on this point.

(*a*) Dr. Banta has continued the selection of *Daphnia* for greatest and for least sensitiveness to light through more than 150 generations (compare Year Book No. 13, p. 131). The results are being prepared for publication.

(*b*) Dr. MacDowell has made the following three experiments upon vinegar flies with extra bristles, outlined in Year Book No. 13, pp. 132–133:

To continue selection till there remains no question as to its effect.—A year ago the report covered selections for 21 generations. At present

the same inbred race constantly selected for the highest numbers of extra bristles is in the forty-second generation. Since the sixth generation no advance has so far been determined that can be interpreted as the result of the selection.

To select in the opposite direction and so produce a race with few or no extra bristles.—It has, so far, been impossible to accomplish this end. Two series of return selections were made and in each of these the progenies from the low-grade parents were as high as those from the high-grade selections. Since the flies with few extra bristles are apt to be the smaller ones, after a few generations of selecting the lines become very weak, and the two series of selections were lost by the failure of the selected flies to produce large enough families from which to make the required selections.

To establish a race of low-grade extra-bristled flies by starting with extras that appeared in the F_2 of a cross with normals.—This has been accomplished. An inbred race that has fewer extra bristles than the high selected line has been obtained by this method. This difference between the two lines is clearly shown, even when both are bred under conditions as nearly identical as can be obtained. The year's work seems, then, strongly to support the conclusion that "selection" as a method of changing the germ-plasm is futile; further support is also afforded the hypothesis, outlined before, that the seeming response to selection shown in the first few generations was due to a sorting of factors, rather than to the modification of a single factor. If there is any significance in these conclusions, the cross between the high-grade and low-grade lines should provide a vital link in the evidence; but pressure of other researches has not yet permitted this.

SELECTION OF BEAN-PLANTS IN NATURE.

Dr. Harris has continued his experiments on selective mortality in nature of bean seedlings, and he planted out this year about 26,000 seedlings selected during the germination of about half a million. It is known that the death-rate is differential; the object of current work is to determine as accurately as possible the selective value of specific morphological features.

SELECTION OF FERTILITY AND FECUNDITY IN PLANTS.

These studies have been carried along by Dr. Harris in connection with other work as usual. Further series of data confirming results on fertility in *Cercis* stated in previous Year Books have been published. An extensive investigation of the relationship between the number of pods per plant and the characteristics of the pod in garden beans—an analysis of the data for 127,610 pods from 19,064 plants grown in 32 experimental cultures made under a wide range of environmental conditions—has also appeared. It is shown that the correlations between the number of pods per plant and the number of ovules per pod in the pods produced have always been found positive in sign, but

numerically low, ranging from 0.023 to 0.355, with an average value of 0.195. For pods per plant and seeds per pod the correlations are also for the most part positive. The values range from −0.046 to +0.338 with a mean of +0.126. By all available tests the correlations for pods per plant and number of ovules per pod seem to be significantly higher than those for pods per plant and number of seeds per pod. Analysis shows, however, that the relationship between the size of the plant and the number of seeds per pod is to some degree independent of that for number of pods per plant and number of ovules formed per pod.

THE PRODUCTION OF AN IMPROVED VARIETY OF SHEEP BY MODERN METHODS.

This research is carried on primarily by the New Hampshire Experiment Station with the collaboration of the Director. By crossing a mutton and a fine-wool type of sheep, and by judicious selection, it is hoped to secure a strain of sheep that will combine the most desirable characteristics. Already in the F_2 generation very valuable combinations of characters have appeared; but it is necessary to breed great numbers to get the desired quality, and by appropriate breeding to fix the desired combination of traits.

ORIGIN OF THE CHARACTERISTICS OF CAVE ANIMALS.

Selection experiments with Cladocera.—These investigations of the problem of the origin of the light-shunning reactions of cave animals give promise of affording further evidence of the validity of Johannsen's hypothesis. The mass of data is large, is being carefully compiled, and will undoubtedly constitute a sound piece of evidence bearing on a hypothesis the universal applicability of which is by no means demonstrated.

Additional Cladocera material.—Four lines of an additional species of *Moina*, of the order Cladocera, are now being kept under control conditions similar to those of the other species mentioned. All the lines of the four species of Cladocera now being bred parthenogenetically are being used in some phase of the experiments regarding the supposed sexual cycle and also in experiments on heredity in parthenogenetic reproduction.

Experiments on the cave problem.—Dr. Banta's experiments upon the effect of light on true cave species and of a cave environment upon outside forms are progressing favorably and as rapidly as the nature of the problem permits. Some additional cave species are being reared in daylight and some additional outside species in a cave environment. The second generation of the amphipod *Eucrangonyx gracilis*, derived from the non-cavernicolous race of this species, reared in the cave, is not yet large enough to determine how much, if any, pigment will be produced. The first-generation offspring derived from the surface stream race of this amphipod kept in the cave show in some individ-

uals a marked, though much reduced, pigmentation; in others only a trace of pigment is developed; and in still others no pigment can be detected. Enough has been seen to conclude that the difference between the outside normally pigmented form of this species and the cave form without body pigment is more than a mere ontogenetic difference, else the first generation offspring reared in the cave from pigmented parents should develop no body pigment.

As throwing light on the albinism of cave forms, Dr. Banta has made some observations on albinos in general. He has published a note giving a number of chance observations on albinos occurring in nature. One of these is the case of a persistent albino strain of the gray squirrel in nature and another is of an albino strain of *Asellus*, which, noted in the same locality for three years, has come to form a notable proportion of the population. It seems here to have undergone no differential elimination.

Exploration of caves.—A collecting trip made by Dr. Banta to the cave region in the Stockbridge limestone (marble and limestone) region of eastern New York, western Connecticut, western Massachusetts, and Vermont proved to be unexpectedly productive. This region contains numerous small caves, each in general known only to people living in its immediate vicinity. These caves are difficult to find and most difficult ones in which to collect. The high altitude of most of these caves is conducive to a limited water content and the sharp tilt of the limestone or marble strata brings about a rapid and complete drainage which is unfavorable for the occurrence of pools suitable for aquatic life. Suitable pools were found in only three of the eleven caves visited in this region. Of these, Newton's Cave, near Pittsfield, yielded no aquatic fauna, although conditions seemed favorable for such life, but in the Twin Lakes Caves near Canaan, Connecticut, two interesting typical cave animals were found, a pigmentless planarian and a small, eyeless and pigmentless amphipod. One of these species may prove identical with a similar form from the cave region in central New York, but this is doubtful. The occurrence of these highly modified species in New England caves from which no real cave fauna had been obtained previously is of much interest. In addition were secured a myriapod, a mite, and a thysanuran, all apparently more or less typical cave animals.

OTHER INVESTIGATIONS.

CORRELATION BETWEEN FERTILITY OF A PLANT AND ITS SOMATIC CHARACTERS.

The ability of a species or strain to hold its own in nature depends, among other things, on its fertility in relation to that of other, closely related, species. Dr. Harris has published a painstaking investigation into the relation between fertility in garden beans—or the average number of mature seeds that a plant produces per pod—and the

number of pods produced on the plant (which varies from 1 to 38 or more). It appears that, on the average, the more pods to a plant the more beans to a pod. This relation is, however, not close; for if perfect correlation be ± 1.00 and no correlation be 0.00, then the correlation found is represented by $+0.126 \pm 0.011$ merely.

RELATION OF PHYSICO-CHEMICAL PROPERTIES OF VEGETABLE SAP TO ENVIRONMENTAL FACTORS.

Dr. Harris and Mr. Lawrence, with the collaboration of the Department of Botanical Research, have been engaged on a continuation of work begun with Dr. Gortner upon the subject that heads this paragraph. Dr. Harris reports:

"Any attempt to influence the germ-plasm of species as a means of controlling evolutionary phenomena should, if it is to throw light upon the problem of the methods by which evolution has taken place in nature, be made by means of factors which are of fundamental biological importance in nature. Such factors are light, temperature, and moisture. Furthermore, the environmental factors chosen should affect not only the soma of the individual, but should have, directly or indirectly, an influence upon the developing germ-cells or fertilized egg. Such work as had been published indicated that soil moisture might be such a factor. It is physically or physiologically widely variable from one region to another, and is of primary importance in determining the characteristics of the vegetation of a region. Furthermore, evidence has been accumulating that the physico-chemical properties of the cell-sap of the plant individual are greatly influenced by this factor of the environment. Thus the immediate environment of the developing zygote may be very materially altered.

"Our objects, then, have been to obtain a comprehensive knowledge of the physico-chemical properties of saps in relation to environmental factors, as a preliminary to controlled experimental studies and transplantation experiments.

"In the field work about 1,400 determinations have so far been made, distributed in round numbers as follows:

Arizona deserts	160
Jamaican coastal deserts	140
Jamaican Blue Mountains, Windward rain forests, and Leeward slopes	480
Long Island mesophytic, hydrophytic, and halophytic habitats	620

"This series of determinations, which is more extensive than all others hitherto published, shows, among other points, that (*a*) there is a relationship between the growth form of the plant individual and the osmotic pressure or diffusion tension of its sap; (*b*) that in the regions studied differences in osmotic pressure of the sap of the plant species are correlated with local environmental factors; and (*c*) that the vegetation of different regions may differ greatly in the physico-chemical properties of its sap.

"The variation from region to region in the osmotic pressure in atmospheres of the extracted sap as determined by the depression of the freezing-point is shown by a comparison of the Arizona deserts with the more mesophytic habitats of Long Island or with the montane rain forests of Jamaica. The average concentration of the juices of the spring vegetation in the region of the Desert Laboratory is 19.4 atmospheres; that for the spring vegetation of Long Island is 11.5 atmospheres. The mean osmotic pressure of the sap of the

species of the Blue Mountain region of Jamaica studied by Shreve (Carnegie Inst. Wash. Pub. No. 199) is 9.4 atmospheres, whereas that of the Port Henderson strand flora, mangrove swamp, and coastal desert vegetation is 30.0 atmospheres. Such general averages, however, give only a fraction of the information necessary. Subdivisions of each of these habitats differ in osmotic pressure. Thus the salt spots of the Arizona deserts show an average of 37.1 atmospheres, whereas the arroyos give a mean of 13.9 atmospheres. On the xerophytic Jamaican coast one locality shows an average concentration of 25 atmospheres, whereas another has a mean of 48. Naturally the general averages for a region as complex as either of those studied will depend in large measure upon the relative number of determinations from each of the subhabitats. In detailed discussions the latter must be made the basis of comparison.

"Furthermore, the growth form of the plant species must be taken into account. Thus Arizona trees and shrubs show a mean concentration represented by 28.2 atmospheres as compared with 14.8 atmospheres for the winter annuals. The mean value obtained for a region will therefore depend upon the proportional frequency in the series of determinations based on the various growth forms. The consideration of all such questions must be reserved until the full data can be presented."

METHODS.

An important statistical study deals with the application of intra-class correlation formulæ to the problem of substratum heterogeneity. In all the plot-culture work of agricultural institutions—whether in the testing of the practical value of newly originated varieties of plants or in fertilizer tests—the factor of the heterogeneity of the field upon which the cultures are to be made must, if results of value are to be secured, receive far more attention. Dr. Harris had employed a formula which measures substratum heterogeneity, as expressed in actual crop yield, in terms of the correlation between associated ultimate plots. It takes the convenient form

$$r_{p_1 p_2} = \frac{\{[S(C_p^2) - S(p^2)]/m[n(n-1)]\} - \bar{p}^2}{\sigma_p^2}$$

where p denotes the yield of an ultimate plot, C_p the yield of a combination plot, $\bar{p}$ the mean yield of the ultimate plots, and σ_p their standard deviation, n is the number of ultimate plots in each of the m combination plots, and S indicates summation, for either the ultimate or combination plots of the field. In this sample formula n is supposed to be constant, but calculation with n variable is only slightly more difficult.

Application of this formula to the best series of data available in the agricultural literature shows that, in practically every field dealt with, substratum heterogeneity might have had a marked influence upon the results of a comparative test.

A paper on spurious values of intra-class correlation coefficients arising from disorderly differentiation within the classes has also been published by Dr. Harris.

Considerable attention has been devoted to the problem of maintaining white rats so that they should not be a nuisance in the building

and should be free from disease. Dr. MacDowell has devised and installed a set of cage-holders (racks) of iron pipe. The cages of half-inch-mesh wire rest on sheet galvanized-iron bottoms, on which layers of blotting paper are placed to absorb odors.

EDITORIAL WORK.

The Whitman manuscripts have been edited assiduously by Dr. Riddle. It will be a source of satisfaction to all biologists that the remarkable results of this thorough and far-sighted geneticist are being made available for study.

STATISTICAL SUMMARY.

PLANTS.

The range of species, number of families, and individuals of each bred in Dr. Shull's experiments are shown in the following table.

Name.	Number of families.	Number of individuals.
Bursa bursa-pastoris	57	5,511
B. bursa-pastoris×heegeri F_1	4	116
B. bursa-pastoris×heegeri F_2	30	6,527
B. bursa-pastoris×heegeri F_4	27	2,557
B. bursa-pastoris×heegeri F_5	43	6,064
B. bursa-pastoris×heegeri F_6	14	2,095
B. heegeri×bursa-pastoris F_3	1	188
B. heegeri×bursa-pastoris F_4	12	797
B. heegeri×bursa-pastoris F_6	51	10,933
B. heegeri	2	250
B. bursa-pastoris apetala	2	189
B. bursa-pastoris rubella	1	69
B. grandiflora	1	125
B. viguieri	1	49
Fragaria spp	6	290
Lychnis dioica	159	8,715
Œnothera atrovirens	1	49
Œ. atrovirens-cleistantha hybrids	4	14
Œ. atrovirens-lamarckiana hybrids	8	140
Œ. atrovirens-venosa hybrids	1	2
Œnothera "biennis CSH"	1	103
Œ. biennis CSH-atrovirens hybrids	2	48
Œ. biennis CSH-cleistantha hybrids	2	73
Œ. biennis CSH-lamarckiana hybrids	2	206
Œ. biennis CSH-venosa hybrids	2	83
Œnothera biennis L.	2	232
Œnothera cleistantha	1	71
Œnothera cleistantha-lamarckiana hybrids	23	1,076
Œ. cleistantha-venosa hybrids	17	786
Œnothera gigas	1	209
Œnothera grandiflora	2	269
Œnothera lamarckiana	13	629
Œ. lamarckiana×brevistylis	2	94
Œ. lata×lamarckiana	1	53
Œ. lamarckiana-venosa hybrids	11	529
Œnothera nanella	1	38
Œ. nanella scintillans	1	27
Œ. nanella hybrids	8	479
Œ. nanella-atrovirens hybrids	2	33
Œ. nanella-cleistantha hybrids	2	30
Œ. nanella-venosa hybrids	2	8
Œnothera oakesiana	2	267
Œnothera robinsonii	2	199
Œnothera rubricalyx	3	267
Œ. rubricalyx-lamarckiana hybrids	3	148
Œ. rubricalyx-rubrinervis hybrids	1	47
Œnothera rubrinervis	11	1,235
Œnothera rubrinervis nanella	1	167
Œ. rubrinervis-atrovirens hybrids	3	47
Œ. rubrinervis-cleistantha hybrids	2	20
Œnothera scintillans	1	52
Œnothera stenomeres	1	37
Œnothera stenomeres gigas	1	52
Œnothera venosa	1	26
Œnothera spp	8	913
Ribes alpinum	2	61
Rumex acetosella	1	65
Rumex scutatus	1	23
Urtica urens	1	45
Valeriana dioica	1	4
Valeriana officinalis	1	4
Valeriana tripteris	1	3
Total	571	53,488

POULTRY.

There were maintained 26 breeding pens and 1,624 chicks were hatched. Selection experiments on plumage color were continued.

SHEEP.

Nineteen lambs were born, giving additional data on twin inheritance, extra nipples, and double horns.

CONSTRUCTION AND EQUIPMENT.

Two additional pigeon-houses (making 4 in all) have been completed, and the grading (including concrete walls and steps) has been done. Extensive grading south of the animal house was done and runs put in place for large mammals. Six sets of concrete cold frames were built in the west garden and two concrete service bridges over the ravine. Part of the earth moved in grading was placed on the salt marsh, increasing the garden area, and the sandier part was used for the foundation of a tennis court, near the animal house. A tool-house and shelter, 12 by 18 feet, were finished at the farm. A shelter for summer work with rats was installed on top of the animal house. The fence around the sheep pasture was painted. The south end of the second floor of the Laboratory was remodeled to meet new needs. Metal racks and cages for the rats were made, and numerous small bits of apparatus and cabinet-work made for the various investigators' rooms.

The largest and most expensive addition to our equipment has been an air-conditioning apparatus to furnish the required temperature and moisture conditions to 4 rooms in the animal house. The general method of refrigeration employed is that of compression of ammonia. The expansion of the ammonia in the tubes cools brine. Moisture and dryness in desired amount are secured and maintained at a constant level, as in the warming apparatus.

GEOPHYSICAL LABORATORY.*

ARTHUR L. DAY, DIRECTOR.

SEGREGATION IN IGNEOUS ROCKS UNDER THE ACTION OF GRAVITY.

Of the causes which may contribute to the segregation of particular groups of minerals (rocks) out of a great mass of molten magma, one of the most important is the condition of chemical equilibrium in consequence of which certain minerals or groups of minerals separate out through supersaturation at particular temperatures and pressures. Of these, many illustrations have been cited in these reports from year to year. Immediately consequent upon this separation there arises the question of the effect of gravity upon the separated portion; whether the viscosity of fluid rocks or the temperature gradient upward or downward or some other counteracting force will enter to prevent the settling out of the nascent crystals, especially when the density differences are small.

Some very patient consideration has been given both to the field and laboratory evidence upon this question during the past year, from which most interesting conclusions have resulted which will certainly help to clear up another of the factors which influence the segregation of the rocks. The field facts are essentially these:

It is known to all that from time to time in various parts of the earth molten rock or lava is poured out upon its surface in greater or less quantity. Perhaps not so generally known is the fact that the molten material at one locality may be quite different in character from that at another, and that even at the same locality the kinds of lava may differ considerably in different eruptions. The masses which have been thrown out at Lassen Peak, California, for example, are entirely different in character from the lava which is boiling in the lake at Kilauea, Hawaii, and some of the material of earlier eruptions in Hawaii differs from both of these.

But the geologist does not confine himself to the study of surface lavas alone in seeking a solution of these problems. The molten rock does not all pour out on the surface. Some of it remains in the feeding-pipe, some may spread out in intercalated sheets in the surrounding rocks, and some may collect in a great subterranean pool. Many such subterranean masses of igneous or once-molten rock are now exposed at the surface, the former cover having been worn away by the ceaseless action of rivers, winds, frost, and the whole array of disintegrating agents. Between different bodies of this kind, and indeed in different parts of the same body, the geologist finds the same kind of variation as he does between different lava-flows. They are in fact the source of the lavas, and the problem of the diversity of lavas becomes the

*Situated in Washington, D. C.

problem of the diversity of their deeper-seated relatives. The slowly cooled subterranean masses of igneous rock are found to consist of a mixture of minerals occurring as crystals. The one rock may be composed entirely of a certain group of minerals, another may contain the same minerals but in very different proportions, and still another may be made up of a wholly different group of minerals. Indeed, the profusion of rock types is so great that they have hitherto baffled satisfactory systematic classification.

From the finished products as he finds them, the field geologist must do his best to infer the processes probably involved in their production; the experimental investigator devises means of testing in the laboratory whether the supposed processes can take place and whether they will produce the result observed in nature.

As long ago as 1844, at a time when petrology was in its infancy, Charles Darwin suggested that the sinking of crystals as they form in the cooling molten rock may be a potent factor in producing diverse rock types. The liquid rock as it cools does not acquire the crystalline or solid state as a unit, but certain of its constituent minerals crystallize at an early stage and others at a later stage. Plainly, then, if the earlier-formed crystals are heavier than the molten material in which they form, they should, under the action of gravity, sink in that liquid. Equally plainly, these portions of rock mass into which a certain kind of crystals moved during this process must become enriched in crystals of that kind, and other portions must be correspondingly impoverished. As we have already seen, it is principally a variation in the proportions of the different kinds of crystals that gives rise to the different rock types. It is but natural that Darwin and later geologists should have held to the view that the sinking of crystals has been a factor in the production of this diversity of types.

It is natural also that the laboratory student should undertake experimental investigations to determine what conditions are favorable to the working of the process and whether the results observed in nature are those which the process gives.

Experiments were therefore instituted with a series of artificial silicate mixtures containing pyroxenes and olivines, members of two common groups of rock-forming minerals. These mixtures had formerly been completely investigated thermally, so that it was known for each mixture at what temperature crystallization would begin, at what temperature it would be complete, and the order of crystallization of its various mineral components. By holding a mixture at a definite temperature at which it was known that both liquid and crystals would be present, opportunity was afforded for the sinking of the crystals. It was found that sinking of both pyroxene and olivine crystals took place quite readily, even in a small crucible. It was noted also that the accumulation of crystals at the bottom increased as the time was

lengthened, and the expected effect of increased viscosity (decreased fluidity) in slowing up the rate of sinking was easily demonstrated by adding silica to the mixtures. In one case, too, of a mineral with exceptionally low density, not common in nature, a floating upwards was demonstrated.

In applying to the case of natural rocks the facts developed experimentally, it is necessary to make due allowance for a difference of conditions. The molten rock is continually cooling, sometimes slowly, sometimes more quickly. The mineral which crystallizes first is shortly joined by crystals of another kind, these two kinds by yet another, and so on as the temperature falls until the time when the whole mass has solidified. During most of the period of crystallization many different kinds of crystals occur in the liquid, the heavier ones tending to sink rapidly and the lighter ones less rapidly, or possibly even tending to float in rare instances. The results should be that they would seriously interfere with one another as far as relative motion is concerned and that the whole mass of crystals would tend to sink rather as a swarm. It is precisely this association of minerals of different densities in the same rock which has led some geologists to conclude that the sinking of crystals can not be an important matter. They reason that the action of gravity, if it is to be regarded as a factor of any considerable importance, should cause a complete sorting of the heavier and the lighter minerals; but it is plain from the above considerations that this is by no means a necessary conclusion. However, in the very earliest stages of the crystallization of a slowly-cooled mass of molten rock, one would expect a considerable degree of sorting of the different kinds of crystals and a greater degree of fluidity than in the later stages. It is noteworthy, therefore, that whenever rocks do consist entirely of crystals of a single mineral, this mineral is always among the few belonging to the generally accepted minerals of earliest crystallization, viz, pyroxene, olivine, the calcic plagioclases, and the iron ores. Not infrequently, too, the heaviest of these minerals have been found accumulated at the bottom of sheet-like masses of igneous rock in a manner which leaves no room for doubt as to their collection under the influence of gravity.

Even in a case where no sorting of individual minerals is accomplished the sinking of minerals of various kinds as a swarm should nevertheless be a potent factor in producing igneous rock types. It should bring about the more or less perfect separation of the minerals of early crystallization as a group from the minerals of the middle period as a group, and both of these from the minerals of the later period. This result is actually found in nature in the common gabbro-diorite-granite sequence.

With an emphatic affirmative, then, experimental investigation answers the query as to whether crystals can sink in bodies of molten

rock. Moreover, the testing of the laboratory conclusions against the results found in nature establishes the importance of this factor in the producing of the great variety of igneous rocks, and enjoins upon us the need of further study of its action.

CALCIUM CARBONATE.

With the same general purpose in mind, some consideration has been given during the past year to one of the important sedimentary rocks. Perhaps the most important single chemical substance found in the sedimentary deposits is calcium carbonate, which occurs as large masses of limestone and marble, also as chalk, coral, and in other forms; moreover, it is being deposited at the present time in many parts of the sea and in many lakes. Indeed, one can hardly overestimate the usefulness to geological science of a thorough knowledge of the conditions under which this substance can form, and of the quantitative importance of the various factors which influence its deposition. The usefulness of such information is enhanced by the fact that it would serve to elucidate a number of problems which at first sight bear no apparent relation to the properties of calcium carbonate.

An instance of such a problem is the proportion of carbonic acid in the earth's atmosphere during its history, for a secular variation of this proportion is very plausibly connected with great climatic changes and especially with the appearance of glacial epochs. One can therefore readily appreciate the reason why calcium carbonate has already formed the subject of a large number of papers, and yet, despite the attention bestowed on it, there are some fundamental points which are still obscure. It appeared probable that some of the outstanding questions could be answered if the existing data were collated, amplified by further experiment where necessary, and interpreted by the aid of the principles of modern chemistry. Such an investigation is under way and the results are very promising.

Perhaps the most important point which hitherto has received inadequate attention (probably by reason of the apparently contradictory character of the experimental data) is the signal effect of changes in the proportion of carbonic acid in the air upon the amount of calcium carbonate which a natural water will hold in solution. Thus if the proportion of carbonic acid falls from 3.5 to 3.0 parts per 10,000 of air, the solubility of calcium carbonate in water in contact with that air will fall from 66 to 63 parts per million. This decrease in the proportion of carbonic acid over a shallow sea would be followed by the deposition of about 2.5 tons of calcium carbonate per square mile for each foot in depth of the water. Indeed, it is plausible that this decrease in the free carbonic acid in the water—a decrease which may be produced in many ways, by organic as well as by purely physical agencies—is the immediate cause of the precipitation of a large part

of the enormous deposits of calcium carbonate present in the crust of the earth, just as its local increase is responsible for the characteristic features of a limestone country.

Again, calcium carbonate exists in two well-known crystalline forms, calcite and aragonite, the latter relatively rare; indeed, this was the first known example of this phenomenon of polymorphism. The relation between these two has been somewhat uncertain, but it is now established that at atmospheric pressure and at all temperatures above 0° aragonite is unstable with respect to calcite and tends to go over into the latter. The rate of the process of transformation depends upon a number of factors, not all yet understood; but under the conditions prevailing in the earth's crust it is very slow. The appearance of aragonite constitutes another cause of the genesis and persistence in time of an essentially unstable form in which the equilibrium is only apparent; a state of things which requires further investigation before general statements with respect to such cases are made.

COPPER-SULPHIDE ORES.

The study of the secondary enrichment of the copper-sulphide ores which was undertaken in collaboration with Professor L. C. Graton, of Harvard University, was reported at some length a year ago. Professor Graton has carried out an elaborate plan of field investigation of the occurrence and environment of these ores, while this laboratory has been pursuing a systematic study of the chemical and physico-chemical relations between the different sulphides and the possible effects of percolating waters upon them. Detailed reports upon various phases of the investigation are in preparation.

It will be recalled that a primary copper-sulphide ore consists of a mass of pyrite or pyrrhotite, in which is embedded a much smaller quantity of the sulphides of copper, copper-iron, etc. Above such an ore-body there is commonly a capping or gossan of oxide of iron of varying thickness, between which and the primary ore is a secondary band of especially rich ore which consists for the most part of chalcocite or cuprous sulphide mixed with smaller quantities of other copper minerals. The primary ore below usually shows no sign of alteration since its original deposition.

These and other facts of field observation have led to the belief: (1) that such ore-bodies consisted originally of primary ore only; (2) that oxidation through the action of moist air occurred upon its exposed surface; (3) that the sulphates formed by this oxidation were dissolved by meteoric water and percolated downward; (4) that copper was precipitated from these solutions by the yet unchanged sulphides, thus forming the enriched ore, while the iron became limonite and formed the capping or gossan.

At the outset the purpose of this inquiry was formulated thus: (1) what are the essential conditions under which any of the important

copper minerals may be formed? (2) what will happen to these minerals when they are exposed in a given environment? The principal copper minerals to which attention is being directed are chalcocite (Cu_2S), covellite (CuS), chalcopyrite ($CuFeS_2$), and bornite (Cu_5FeS_4). Of these, chalcocite and covellite have been thoroughly studied during the year just past, and an account of their formation under measured conditions in the laboratory, together with their relation to each other, their stability at various temperatures, their specific gravity, and other properties, will be found reviewed on pages 165 and 166.

One property of chalcocite is of considerable geological interest. It shows a readily reversible change of state at about 91°, which has been clearly brought out both in its thermal behavior and in the change in its electrical resistance. All chalcocites, synthetic or natural, which contain no excess of sulphur show this change. It has also been established with reasonable certainty that this change accompanies a transformation from the isometric to the orthorhombic crystal form. The isometric form in measurable crystals is obtained by both wet and dry methods at all temperatures from the melting-point down to 200°, between which temperature and 91° no evidence of change can be detected.

All crystals of Cu_2S hitherto found in nature have been orthohrombic; hence we infer that this chalcocite, whether primary or secondary, has been formed below 91°, and this is the lowest temperature yet established on the "geologic thermometer." It would seem probable, nevertheless, that much massive chalcocite in nature must have been formed above this temperature, and a thorough search for natural isometric chalcocite ought to be made.

Chalcopyrite and bornite are more complex substances and have been much more difficult to deal with, but an apparatus has now been developed for the systematic investigation of the whole system Cu–Fe–S, with the aid of which all the known phases of the system, viz, pyrite, pyrrhotite, chalcopyrite, bornite, chalcocite, and covellite, have been prepared synthetically in such form that they can be handled easily by the microscopist. The manner of studying these has been through their dissociation-pressure curves. The method consists in ascertaining for a given temperature two sulphur-vapor pressures near together, at one of which a sulphide dissociates (loses sulphur), while at the other it remains undissociated or its dissociation product absorbs sulphur. Between these two pressures lies the equilibrium pressure.

In this way it is possible to discover the boundaries which limit the domain of stable existence for each of these minerals. This information is not alone of theoretical importance, but may find direct application in copper-smelting practice.

The sulphides which have been considered in connection with the process of secondary enrichment are chalcocite, covellite, chalcopyrite,

bornite, pyrrhotite, pyrite, sphalerite (ZnS), and galena (PbS). Except for tetrahedrite and enargite, which may be set aside for the moment on account of their chemical complexity, these are all of the important minerals of the primary ores. The three most important constituents of the enriching solutions are copper sulphate, ferrous sulphate, and sulphuric acid, all formed by the surface oxidation of the sulphides in the air. The effect of these three constituents, singly and in various combinations, on the aforementioned sulphides has now been studied. The reactions are very slow at the temperature of the earth's surface, at or near which they proceed; so slow that a number of previous attempts to discover them in the laboratory have failed utterly. Our preliminary work was therefore done at 200°, with the sulphide finely powdered to increase the reacting surface, and with solutions of low concentration. The containing vessels were of quartz glass. In this way, with the material aid of the microscope for the diagnosis of the products, the quantitative relations between the solutions and sulphides at this temperature were worked out.

With knowledge gained in this way it has been possible to interpret results at lower temperatures. Experiments were made at 100° and at 40°. Those at 40° required from 1 to 2 months for each experiment and the use of mechanical shakers running continuously, which kept the powdered sulphide suspended in the liquid and thus continually exposed to its action.

Summarizing the results of this action of the enriching solutions on the sulphides: copper sulphate alone changes them all eventually into chalcocite, *i. e.*, copper precipitated from the solution and the copper in the sulphides both take that form as the end-product. The course of the reaction varies with different sulphides. The simple sulphides sphalerite and galena first give covellite (CuS) chiefly, as if there were a simple interchange of the metals

$$ZnS + CuSO_4 = ZnSO_4 + CuS$$

But covellite itself is slowly changed to chalcocite by copper sulphate. In this rather curious reaction copper sulphate appears as an oxidizing agent, removing half the sulphur from the sulphide as sulphuric acid

$$5CuS + 3CuSO_4 = 4Cu_2S + 4SO_3$$

Indeed, in its action on the other sulphides, copper sulphate behaves as an oxidizing agent, changing the iron to ferrous sulphate and the sulphur in part to sulphuric acid.

Pyrrhotite shows rather unique behavior with copper sulphate in that the first product is chalcopyrite. But since chalcopyrite is changed finally to chalcocite, so pyrrhotite, if subjected to the action of copper sulphate for a sufficiently long time, gives chalcocite.

Ferrous sulphate solution in the presence of copper sulphate undoubtedly accelerates enrichment. It is surmised that the cause of this

influence is the partial reduction of the copper to the cuprous condition in which it is more readily precipitated. If this be true, more of the copper in the precipitate should be in the cuprous condition when ferrous sulphate is added. This point will be investigated further, for it raises an interesting question. Unless ferrous sulphate is present in the enriching solutions the product always contains cupric sulphide unless repeatedly treated with cupric sulphate. A part of this cupric sulphide, at least, appears to exist in the chalcocite in a dissolved state. Such chalcocites are found in nature and are perhaps the product of enriching solutions which contained little or no iron.

We have now a method for distinguishing readily between chalcocites which do and those which do not contain cupric sulphide, and propose to investigate a considerable number of them from various fields where the geological relations have been studied, with the purpose of ascertaining whether enriching solutions which contain very little ferrous iron give chalcocites of a different composition.

The third constituent of the enriching solutions, sulphuric acid, has an appreciable effect on the process of enrichment. With both pyrite and chalcopyrite, the addition of 1 to 2 per cent of sulphuric acid to the copper sulphate caused retardation of the enrichment. On the other hand, galena, sphalerite, and bornite, which react readily with sulphuric acid to produce hydrogen sulphide, bring down copper more rapidly from enriching solutions which contain free sulphuric acid, because the hydrogen sulphide precipitates copper immediately.

A number of other reactions have been worked out between the primary sulphides and single constituents of the enriching solutions and with some other substances which may occur locally in the enrichment zone. Such products may be economically unimportant in the geology of a region, but economically unimportant minerals sometimes furnish the key to economically important conditions of precipitation. Thus dilute sulphuric acid at 40° decomposes bornite readily, with the formation of covellite, chalcocite, ferrous sulphate, and hydrogen sulphide, while at 200°, chalcopyrite and pyrite or marcasite are obtained in addition to the above.

Dilute sulphuric acid (as low as 40°) with a mixture of pyrrhotite and chalcocite (or covellite) gives ferrous sulphate, hydrogen sulphide, chalcopyrite, and pyrite or marcasite. Bornite is also a product of this reaction if the copper sulphide is in excess. Pyrrhotite and chalcocite (or covellite) with hydrogen-sulphide water give chalcopyrite at 40°. At higher temperatures bornite is a product of this reaction when the copper sulphide is in excess, but the bornite is formed under a protective covering of chalcopyrite.

Chalcopyrite has not yet been found as a direct product of enrichment on any sulphide except pyrrhotite, nor has bornite been found as an enrichment product of any sulphide. However, both chalco-

pyrite and bornite, which occur in minor quantities in the enrichment zone, have been synthesized by reactions which may possibly take place there. Secondary pyrite or marcasite—probably both—have been prepared by reactions which may sometimes occur in the enrichment zone. It must be remembered, however, that both these minerals, as well as bornite and chalcopyrite, are by further action of copper sulphate eventually changed to chalcocite.

When these data are carefully compared with known geologic data, it is hoped they will throw some light on a number of absorbing questions in geology, *e. g.* (1) How much of the oxidation of an ore body is accomplished directly by the air and how much by copper sulphate? (2) Does enrichment take place above or below the water-level? (3) Why is the zone of enrichment so sharply differentiated from the gossan as we find it in nature?

PUBLICATIONS.

Brief reviews of the papers published by members of the Laboratory staff during the current year follow:

(1) Water and volcanic activity. Arthur L. Day and E. S. Shepherd. Smithsonian Report for 1913, 275–305.

Reprinted by permission from the Bulletin of the Geological Society of America, 24, 573–606, 1913. Reviewed in Year Book No. 12, p. 146.

(2) Crystallization-differentiation in silicate liquids. N. L. Bowen. Am. J. Sci. (4), 39, 175–191 (1915).

Experiments with viscous molten silicates were undertaken in order to ascertain whether the sinking or floating of the crystals which formed could be observed. The sinking of olivine and pyroxene and the floating of tridymite were quite readily observed in various mixtures of the system diopside-forsterite-silica.

With the rate of sinking of the crystals as a basis, rough estimates were made of the viscosity of the melts, and they show, as might be anticipated, a progressive increase of viscosity with increase of silica.

As an illustration, attention is called to the importance of the sinking of olivine crystals in the Palisade diabase sill, to which J. V. Lewis has already given some consideration. In the opposite sense, contact chilling may, by restricting the sinking of crystals, bring about the formation of a basic contact phase.

The fact is pointed out that the sinking of crystals can not safely be considered negligible, even in acid magmas occurring in large bodies.

(3) The accurate measurement of the refractive indices of minute crystal grains under the petrographic microscope. Fred. E. Wright. J. Wash. Acad. Sci., 5, 101–107 (1915).

In the exact measurement of refractive indices of minute crystal particles by the immersion method it is essential: (*a*) that correctly oriented sections be selected which are normal to at least one principal optic section; (*b*) that in case oblique illumination be used, only those pencils of light be employed whose direction of propagation is included in the plane normal to the principal optical section—in other words, the metal sliding-stop should be so inserted

that its front edge is parallel to a principal section; (c) that with central illumination special weight be given to the effects along those edges of the grain which trend approximately parallel to the principal section. If these conditions be disregarded the value obtained for the maximum refractive index will be too low, the value for the minimum refractive index too high, while that of any intermediate refractive index, as β, may be too high or too low. Failure to recognize these factors may lead, especially in the case of strongly birefracting crystal particles, to refractive-index determinations which are appreciably in error.

(4) The measurement of the freezing-point depression of dilute solutions. L. H. Adams. J. Am. Chem. Soc., 37, 481–496 (1915).

It is a matter of some importance to ascertain with accuracy the relation between the freezing-point and the concentration of a solution, for at the present time this constitutes the most accurate means of determining the number of moles present in the solution; and it is desirable to have such observations for dilute aqueous solutions of salts, where comparison of the results with those derived from conductance measurements is possible. Accurate data have hitherto been few in number, for the reason that not enough attention has in general been given to the necessity of determining with sufficient accuracy both the temperature and the concentration of the solution in equilibrium with the ice. The present paper is a detailed description of a method of measuring the freezing-point depression of dilute solutions by the use of which one is enabled to observe the equilibrium temperature with an uncertainty no greater than 0.0001° and to determine the equilibrium concentration with commensurate accuracy. The depression is measured directly by means of a 50-junction copper-constantan differential thermo-element (which gives 2,000 microvolts per degree) and a potentiometer system which enables the electromotive force to be read to 0.1 microvolt. A prerequisite for the attainment of this degree of accuracy is a condition of stationary equilibrium between ice and solution. This is secured by thorough mixing (by means of a specially designed stirrer) of the solution with a large quantity of ice in a vacuum-jacketed vessel completely surrounded by melting ice. The concentration of the equilibrium solution is determined by a zero method in which an interferometer is used as a means of comparison. The sensitiveness of this method is about 2 parts of solute per million of water.

Results are presented for solutions of the non-electrolyte mannite and of the salts potassium nitrate and chloride at concentrations ranging from 0.004 to 0.1 molal; consideration of these results shows that the method is susceptible of the accuracy claimed for it. The mole-numbers for the two salts, as calculated from the measurements, agree well with those derived from conductance data at the lowest concentrations, the only region within which such agreement is significant.

(5) The system anorthite-forsterite-silica. Olaf Andersen. Am. J. Sci. (4), 39, 407–454 (1915).

In the study of the system anorthite-forsterite-silica the following solid phases were observed: anorthite, forsterite, cristobalite, tridymite, clinoenstatite, and spinel. The paper describes thermal-microscopic studies of artificial mixtures of the compounds $CaAl_2Si_2O_8$, Mg_2SiO_4, and SiO_2. The thermal data were almost exclusively obtained from quenching experiments and the microscopic examination was undertaken on the powdered quenched products.

The equilibrium relations of mixtures of anorthite, forsterite, and silica can not in general be explained in terms of a ternary system with these compounds

as components, nor in terms of any other ternary system. This is due to the reaction which takes place between anorthite ($CaAl_2Si_2O_8$) and forsterite (Mg_2SiO_4) with the formation of spinel ($MgAl_2O_4$) as a primary phase. The composition of the liquid and the general relations of that part of the system where spinel occurs can be expressed no more simply than in terms of the four-component system $CaO–MgO–Al_2O_3–SiO_2$. The greater part of the mixtures, however, behaves as if the system were a true ternary one, and that part has been made the subject of detailed examination.

The solid phases occurring in the system are the following: anorthite ($CaAl_2Si_2O_8$), forsterite (Mg_2SiO_4), cristobalite (SiO_2), tridymite (SiO_2), clinoenstatite ($MgSiO_3$), and spinel ($MgAl_2O_4$).

The binary systems.—The system forsterite-silica is described in a previous paper. The system anorthite-silica is a true binary system with a eutectic point of composition anorthite 52 : silica 48 at the temperature $1353° \pm 2°$. The system forsterite-anorthite is not a true two-component system, spinel being formed as a primary phase in mixtures between forsterite 14 : anorthite 86, at $1444° \pm 2°$, and forsterite 45 : anorthite 55, at $1465° \pm 2°$. Outside the interval between these mixtures the primary phases are forsterite or anorthite, respectively, and the crystallization takes place as in normal two-component systems until the composition of the liquid has reached one of the two points mentioned.

The ternary system contains two quintuple points: (1) The point where the fields of anorthite, forsterite, and clinoenstatite meet; composition, anorthite 55, forsterite 25.5, silica 19.5; temperature $1260° \pm 2°$. This point is not a ternary eutectic but a reaction point. (2) The ternary eutectic anorthite, clinoenstatite, silica; composition, anorthite 50.5, forsterite 16.5, silica 33; temperature $1222° \pm 2°$.

A discussion is given of the course of crystallization of typical mixtures on cooling under equilibrium. It appears that forsterite (Mg_2SiO_4) occurs as a primary phase under the normal crystallization of certain mixtures in spite of the fact that these mixtures contain silica in excess over the ratio in which SiO_2 and MgO form $MgSiO_3$. The composition of these mixtures is expressed by points lying between the conjugation line and the field boundaries, forsterite : clinoenstatite and forsterite : anorthite. At a later stage of crystallization there is a reaction between the forsterite thus formed and the remaining liquid, this reaction always resulting in complete solution of the forsterite and a simultaneous crystallization of clinoenstatite. When the reaction is over, the crystallization continues toward the ternary eutectic anorthite–clinoenstatite–silica, in various ways, according to the initial composition of the mixture. In other mixtures which have forsterite as a primary phase, namely, those whose composition is expressed by points on the forsterite side of the conjugation line, forsterite is only partly dissolved and the crystallization is now complete at the reaction-point (the first quintuple point referred to).

The bearing of the equilibrium relations here indicated on petrological problems is discussed.

(6) Das ternäre System: Anorthit-Forsterit-Silicium-2-Oxyd. Olaf Andersen. Neues Jahr. Min. Geol. (in press).

A German translation of "The system anorthite–forsterite–silica" (Am. J. Sci. (4), 39, 407–454, 1915). Reviewed under No. 5 above.

(7) Some notes on the theory of the Rayleigh-Zeiss interferometer. L. H. Adams. J. Wash. Acad. Sci., 5, 265–276 (1915).

In the course of some work on the freezing-point of dilute aqueous solutions, in which a Zeiss interferometer was employed as a means of determining the

concentration of the equilibrium solution (see No. 4, "The measurement of the freezing-point depression of dilute solutions"), some trouble was experienced at first in obtaining thoroughly concordant readings; this was found to be due to an alteration of the achromatic reference fringe produced by differences in optical dispersion. In order to guard against error from this source it proved necessary to investigate the relationships in order to derive formulæ from which the exact amount of shift of the achromatic fringe could be predicted. The appropriate formulæ for this type of instrument have apparently not been worked out heretofore; consequently it has seemed worth while to call attention to these relationships and to put the formulæ on record so as to save trouble to future users of this most useful type of instrument. By means of these formulæ, one is enabled to interpret the readings of the instrument in terms of refractive-index differences and to predict in advance the exact amount of shift of the achromatic reference fringe due to differences in optical dispersion. (*Cf.* No. 8, "The use of the interferometer for the analysis of solutions.")

(8) The use of the interferometer for the analysis of solutions. L. H. Adams. J. Am. Chem. Soc., 37, 1181–1194 (1915).

Chemists have long used the refractometer as an aid in analytical work, but have not made use of the interferometer to the extent that its precision and general convenience would warrant. The use of the ordinary forms of refractometer is limited by the circumstance that the change of refractive index with temperature is usually such as to require regulation of temperature to 0.01° in order to secure an accuracy of one unit in the sixth place in the measurement of refractive index. By means of the interferometer, on the other hand, it is a simple matter, requiring no special regulation of temperature, to secure an accuracy of one unit in the seventh place; this is possible because in the latter case we are comparing the refringence of one liquid (or gas) with that of another of very nearly the same composition and hence possessing almost the same temperature coefficient of refringence. In other words, with the refractometer one can determine the composition of a solution to 2 parts in 10,000 of solvent, but with the interferometer—provided that certain simple precautions be observed—to 2 parts in 1,000,000. The interferometer is adapted to the determination in any transparent mixture of a single varying component; this component may be solute or solvent, electrolyte or non-electrolyte, indeed, any substance which will not attack the instrument.

This paper presents a brief description of a convenient form of interferometer for chemical purposes, discusses its mode of operation, and points out the precautions to be observed in its use. The only important source of error arises from differences in optical dispersion; this can, however, be readily obviated by the use of the methods recommended.

(9) A vacuum furnace for the measurement of small dissociation pressures. R. B. Sosman and J. C. Hostetter. J. Wash. Acad. Sci., 5, 277–285 (1915).

This paper describes a vacuum furnace and accessory apparatus adapted to the measurement of a wide range of dissociation pressures of iron oxides and silicates. The furnace consists essentially of two parts: (1) the furnace-tube, which serves both as the furnace-wall inclosing the "inside vacuum" and as the heating element; (2) the water-cooled jacket which surrounds the furnace tube and incloses the "outside vacuum." The furnace-tube is 15 mm. inside diameter, and made of an alloy of 80 parts platinum and 20 rhodium. Three gages provide a possible range of pressure measurement from 0.000001 mm. mercury up to 2.5 atmospheres. The uniformity of tem-

perature was tested by taking a series of measurements of the oxygen pressures produced by 0.5-gram charges of iron oxide, heated at various levels in the furnace. These indicate a length of about 25 to 30 mm., within which the temperature is uniform within 1°. The furnace takes 580 amperes at 1.8 volts at 1450°, and can be held constant to 1° at this temperature.

(10) Ein Vakuumofen für die Messung kleiner Dissoziationsdrucken. R. B. Sosman und J. C. Hostetter. Z. Elektrochemie (in press).

A German translation of "A vacuum furnace for the measurement of small dissociation pressures" (J. Wash. Acad. Sci., 5, 277–285, 1915). Reviewed under No. 9 above.

(11) The reduction of iron oxides by platinum, with a note on the magnetic susceptibility of iron-bearing platinum. R. B. Sosman and J. C. Hostetter. J. Wash. Acad. Sci., 5, 293–303 (1915).

Platinum acts on both hematite and magnetite at 1200° under low pressures of oxygen, absorbing iron and giving off oxygen. It also reacts with magnetite in the same way at 1600° and at the usual atmospheric pressure of oxygen. (Hematite is not stable in air at 1600°, but goes over into magnetite.) On the other hand, it is well known to analysts that platinum crucibles in which Fe_2O_3 is ignited in air for weighing in analytical procedures take up no such amounts of iron as were found to be absorbed under the conditions just described. The reason for these differences of behavior is readily found in the phase rule and the relations of iron and platinum in their alloys. The results explain the very common occurrence of small amounts of iron in platinum, since platinum will exercise its reducing action on any material containing iron oxides with which it comes in contact, provided the temperature is sufficiently high. At low temperatures, on the other hand, and with abundant access of atmospheric oxygen, no appreciable reduction is to be expected. The magnetic pull exerted by an electro-magnet on a sample of iron-bearing platinum gives only a qualitative indication of the presence of iron, but no quantitative measure of the amount present.

(12) The calculation of calcium orthosilicate in the norm of igneous rocks. H. S. Washington. J. Wash. Acad. Sci., 5, 345–350 (1915).

In calculating the norm of igneous rocks according to the quantitative system, the akermanite molecule, $4CaO.3SiO_2$, was used in certain cases. Recent researches in the Geophysical Laboratory have shown that this molecule is non-existent, that $3CaO.2SiO_2$ is unstable, but that $2CaO.SiO_2$ is stable and readily formed in melts low in SiO_2 and high in CaO. This molecule has accordingly been adopted instead of $4CaO.3SiO_2$, and this paper presents the appropriate new equations for its calculation, with examples, as well as a short description of a modified procedure in calculating the norms of igneous rocks.

(13) Contributions to Sardinian petrography. I. The rocks of Monte Ferru. H. S. Washington. Am. J. Sci. (4), 39, 513–529 (1915).

It is purposed to publish a number of analyses of Sardinian igneous rocks which have been made in recent years upon material collected in 1905, beginning with those of Monte Ferru, on the west coast of the island.

The geology and structure of the volcano are briefly described. It is composed of a huge central dome of trachytes, with subordinate phonolite, and covered with a thick mantle of basalts. There are some small final flows of analcite basalt. The main types are described petrographically, and eight chemical analyses are given.

(14) Covellite: A singular case of chromatic reflection. H. E. Merwin. J. Wash. Acad. Sci., 5, 341–344 (1915).

The mineral covellite, CuS, in the finest powder is deep blue. Thin flakes (less than 0.001 mm.) in transmitted light are green. Immersion in liquids of high refraction causes covellite to reflect red or purple from obliquely incident white light. Absorption is not strong enough to account for the color effects. The refractive index, ω, for red is less than 1, for yellow 1.5, for blue-green 2. Oblique reflection from such a material in air gives a preponderance of blue; in highly refracting liquids red and orange predominate because of total reflection. The character of the reflection from sections normal to the cleavage shows that ϵ is greater than ω for all colors.

(15) Mechanical strain and thermoelectric power. Walter P. White. Phys. Rev., 6, 234–236 (1915).

It is difficult to specify definitely either the amount or character of the changes due to permanent mechanical strain in metals; it is even uncertain what they consist in, and yet their effect upon the thermoelectric power may throw light upon the important and obscure questions which exist regarding the relations of electricity to metals. A few observations upon this effect are therefore given.

In general, the effect of alloying a metal is to lower the thermoelectric power. The effect of hardening by permanent strain (bending, drawing through dies, etc.) either a pure metal or an alloy is to *raise* the power. Hence hardening has an opposite effect to alloying, though of less amount. Platinum alloys, however, are most of them higher than platinum. And the alloy of platinum containing 10 per cent of rhodium (and probably other platinum alloys also) is lowered by mechanical hardening, so that here also alloying and hardening have effects opposite to each other. Pure platinum, however, is changed in the same direction by hardening and (usually) by alloying. One probable result of this opposite behavior of pure platinum and its alloys is that there are alloys of such compositions that hardening has no effect on their thermoelectric power.

The thermoelectric effects of temporary strain (strain below the elastic limit) have no perceptible relation to those due to permanent strain, or hardening. In fact, hydrostatic pressure and tension produce, in a number of cases, opposite effects. Hydrostatic pressure, like hardening, usually raises the thermoelectric power, whence it follows that tension has the opposite effect to hardening. But even this is not true for all metals. Manganin, which is exceptional for both tension and pressure below the elastic limit, is raised, like most other metals, by hardening, while platinum-rhodium is not exceptional for temporary strains.

A certain sample of constantan wire, hardened by drawing from 2.5 to 0.25 mm. diameter, was softened by careful annealing near 800°. Another portion of the same, annealed near 300°, remained mechanically rather hard, but was as soft, *i. e.*, as low, thermoelectrically as the other. *A metal, therefore, may be in a state of relative mechanical hardness without possessing the corresponding thermoelectric condition.* The same effect has been observed with platinum, which is generally annealed perfectly at a dull red heat, though not then so soft mechanically as after a heating to 1300° or so. In one instance, however, the thermoelectric power was lowered by a high heat after it had become apparently constant by heating to a dull red.

Even in a short communication upon thermoelectricity, it seems necessary at the present time to specify what convention is used regarding the sign of the thermoelectric power. The best authorized notation, used from the dis-

covery of thermoelectricity in 1821, and sanctioned by the leading texts and collections of tables in English, French, and German (with the exception of Mascart and Joubert), defines that metal as positive from which the current flows at the cold junction. This makes antimony, iron, copper, and platinum-rhodium positive to platinum, mercury, nickel, constantan, and bismuth. The opposite notation has, however, been used in some cases, with the result of causing much confusion.

(16) Nephelite crystals from Monte Ferru, Sardinia. H. S. Washington and H. E. Merwin. J. Wash. Acad. Sci., 5, 389–391 (1915).

Nephelite from miarolitic cavities in a trachytic phonolite has lower refraction and is different crystallographically and chemically from other known nephelites. The differences are shown in this paper by comparative tables.

(17) The constituents of portland cement clinker. G. A. Rankin. J. Ind Eng. Chem., 7, 466–474 (1915).

In attacking a complex problem such as the question of the constituents of portland cement clinker, one must proceed in a systematic manner. After ascertaining which are the essential components, one must determine by experiment just how these components combine under the particular conditions, and the nature and mutual relations of the several compounds formed; this involves the investigation of the composition, the number and relation of the various crystalline forms of the several compounds, and their optical characteristics, as well as the study of the state of equilibrium reached by mixtures of all compositions throughout the range of temperatures. One is then able to state precisely what will happen when any mixture of the components is heated or cooled slowly (so that equilibrium is continuously attained) and to indicate the course and final products of reaction when equilibrium is approached but not completely attained.

The essential chemical components of portland cement are CaO, Al_2O_3, SiO_2. From the results obtained during a systematic study of the system CaO–Al_2O_3–SiO_2 we have found that these three oxides *alone* in the proportions in which they occur in commercial portland cement, when perfectly burned, will produce a clinker made up only of the constituents (compounds) $2CaO.SiO_2$, $3CaO.SiO_2$, and $3CaO.Al_2O_3$. This clinker possesses all the properties of a desirable portland cement when it is ground and treated with water.

White commercial portland cement has a CaO, Al_2O_3, SiO_2 content of over 95 per cent, while the more common gray variety of cement contains over 90 per cent of these three oxides. Examinations of the clinker of these two types of cement have shown that the main constituents (over 90 per cent) are $2CaO.SiO_2$, $3CaO.SiO_2$, and $3CaO.Al_2O_3$, and that the minor constituents (less than 10 per cent) are $5CaO.3Al_2O_3$, CaO, and ferrites.

It may, therefore, be definitely stated that portland cement clinker is made up largely of the three CaO–Al_2O_3–SiO_2 compounds, $2CaO.SiO_2$, $3CaO.SiO_2$, and $3CaO.Al_2O_3$, and it seems probable that the desirable properties of portland cement are due to these three major constituents and that the minor constituents have little, if any, influence upon it.

It has been argued by some that not even an approximation to equilibrium conditions obtains in the actual manufacture of portland cement, and hence that conclusions derived from a study of the equilibrium diagram of this system would have little or no bearing on the question of the constituents of commercial clinker. It may be that equilibrium conditions are not always completely attained in the burning of commercial clinker, but the work on actual clinkers already published from the laboratory of the Bureau of Stand-

ards, which was based upon the equilibrium diagram of the system $CaO-Al_2O_3-SiO_2$, has disproved this as a general contention. Indeed, one must conclude that the nearer the approach to equilibrium the better the resultant cement, judging from the great stress which is now laid on fine grinding of the raw materials and from the lengthening out of the cement kilns—factors which, by securing more intimate contact of the two components and by increasing the period of heating, obviously make for a nearer approach to equilibrium. Just how close an approach to equilibrium (perfect burning) is desirable or economically possible, can not be stated from the data available; these data can only be obtained, for a given raw mix, by investigation. Such an investigation would necessitate careful research to determine the relation between time, temperature of burning, and fineness of grinding of given raw materials, in order to produce good clinker at the lowest possible cost to the manufacturer.

Actual cement clinker contains small quantities of MgO and iron oxide, which are advantageous in that their presence during burning promotes the attainment of equilibrium by lowering the temperature at which liquid appears (fluxing) and by increasing the amount of such liquid; but they would seem—to judge from the available reliable evidence—to have little influence on the final main constituents of the clinker. This latter statement, be it noted, refers only to the clinker, and implies nothing as to whether such admixtures have or have not a beneficial influence on the cementing qualities of the product when mixed with water.

Now that the constitution of the clinker has been definitely established, it is practicable to attack the problem of the hydration of portland cement; indeed, the results of an investigation along this line have already been published from the Pittsburgh laboratory of the Bureau of Standards. By ascertaining precisely what happens on the hydration of each possible constituent of the clinker separately and in all the possible permutations and combinations, it should finally prove possible to determine the proportions of the various constituents which should be present in the clinker in order to produce a cement which on setting will possess the most desirable qualities, *e. g.*, the greatest strength; and from a study of the equilibrium diagram one can learn just how to proceed in order to produce a clinker of this optimum composition. In conclusion it may be remarked that the effect of admixture of other materials can only be definitely ascertained by the systematic and somewhat laborious procedure described above—a procedure which, nevertheless, will lead sooner to the discovering of the optimum composition in various cases and for various purposes than the empirical or cut-and-try method which hitherto has been the only method employed.

(18) Die Bestimmung der Dichte von Mineralien und Gesteinen bei hohen Temperaturen. Arthur L. Day, R. B. Sosman, und J. C. Hostetter. Neues Jahr. Min. Geol., 40, 119–162 (1915).

A German translation of "The determination of mineral and rock densities at high temperatures" (Am. J. Sci. (4), 37, 1–39, 1914). Reviewed in Year Book No. 12, p. 144.

(19) The crystallisation of haplobasaltic, haplodioritic, and related magmas. N. L. Bowen. Am. J. Sci. (4), 40, 161–185 (1915).

Mixtures of diopside with various members of the plagioclase series, referred to as haplobasaltic (from the Greek ἁπλόος = simple), haplodioritic, and so forth, according to the nature of the plagioclase, are studied by the quenching method of thermal analysis. Equilibrium, determined in this manner, is

represented graphically in several diagrams. All the determinations which are necessary for the complete description of the crystallization of any mixture have been made and are presented. The facts determined for haplobasalt, haplodiorite, and so forth, are applied to their natural analogues, and it is shown that there can be little reason to doubt that crystallization controls the differentiation of the subalkaline series of igneous rocks.

(20) Das ternäre System Diopsid-Anorthit-Albit. N. L. Bowen. Z. anorg. Chem. (in press).

A German translation of "The crystallization of haplobasaltic, haplodioritic, and related magmas" (Am. J. Sci. (4), 40, 161–185, 1915). Reviewed under No. 19 above.

(21) Obsidian from Hrafntinnuhryggur, Iceland: Its lithophysæ and surface markings. Fred. E. Wright. Bull. Geol. Soc. Amer., 26, 255–286 (1915).

The obsidian at Hrafntinnuhryggur, near Myvatn, Iceland, is of special interest to the geologist because of the unusual opportunity it offers for the study of the effects resulting from the physico-chemical conditions of cooling. In this paper the formation especially of spherulitic, lithophysal, and pumiceous structures is discussed; certain remarkable surface markings resembling the pits and grooves on moldavites are also described briefly. They were produced by the etching effect of hot volcanic emanations on fragments of obsidian glass. All the evidence indicates that in the formation of lithophysæ gases were active. These volatile components, which were released from the magma during the crystallization of the radial spherulites, attacked part of the material of the spherulites; new crystal compounds, such as tridymite and fayalite, were formed which bespeak conditions of formation different from those under which the original spherulites were crystallized. The pressure of the liberated volatile components aided materially in the original formation and subsequent enlargement of the lithophysal cavities. The general hydrostatic tension (external pull) resulting from shrinkage of the central part of the cooling magma probably aided in this development, but it was a less important factor than the inclosed gas pressing against the walls of the cavity.

Volatile components set free during the crystallization of a spherulite may either escape along minute cracks and spaces in the spherulite to its margin and there form a bubble in the viscous magma, or the viscosity of the magma may be such that the internal gas pressure forces asunder the spherulite. In the first case the presence of the gas bubble adjacent to the spherulite hinders the further growth of the spherulite at that point, with the result that the spherulites with adjacent bubble cavities are well developed. In the second case it is important to note that the forcing apart of the cavity was a very slow process. The first rupture took place when the spherulite was small and the rigid walls of the cube were forced back and grew accordingly as crystallization proceeded. The edges of the cube were thin and in contact with the magma, which, however, was probably so thick and viscous that less resistance was offered to the slow forcing apart of the walls of the spherulite than to the formation of gas bubbles adjacent to the spherulite. It is not possible to determine, from the scant evidence at hand, the several quantitative factors which are essential to the formation of the type of lithophysal cavities described in this paper.

Evidence is also presented which shows clearly that the deeply etched surfaces on irregular fragments of the obsidian are the result of etching by hot circulating solutions from which large amounts of hyalite were deposited. Minute crystals of alunite were also deposited during a later stage of circulat-

ing solutions. The close resemblance of the surface etching phenomena thus produced to the surface of moldavites and other tektites is emphasized; also the mechanics of the etching process by which such extraordinary forms are obtained. The distribution of strain within the moldavites is considered briefly. The conclusion is reached that neither the external form of the moldavites nor the distribution of strain within them can be considered to be an indication of their extraterrestrial origin, as has been stated by Suess. This conclusion is identical with that recently advanced by Merrill, and the above evidence serves to strengthen the position taken by him.

(22) The solubility-product constant of calcium and magnesium carbonates. John Johnston. J. Am. Chem. Soc., 37, 2001–2020 (1915).

In connection with certain calculations undertaken with the object of ascertaining the nature and character of the solid deposited when solutions containing both calcium and magnesium carbonates are evaporated down, it was necessary to have trustworthy values of the appropriate solubility-product constants. Owing to lack of the proper experimental data, all of the constants required for the solution of the problem could not be evaluated; but the data proved sufficient to yield satisfactory results for the solubility-product constant of calcium carbonate (calcite) and of magnesium carbonate trihydrate (nesquehonite). The experimental determinations of the solubility of calcite were made with partial pressures of carbon dioxide ranging from about 0.0005 atm. (which is slightly greater than the amount ordinarily present in the air) to 6 atm.; yet, in spite of this ten thousand fold variation of one of the factors in the equilibrium, the calculated solubility product remains constant, a fact which demonstrates the substantial accuracy of the assumptions involved in the calculations.

The results are: $K_C = [Ca^{++}]\,[CO_3'']=0.98\times10^{-8}$ at 16°, when the solution is saturated with respect to calcite; $K_N=[Mg^{++}]\,[CO_3'']=1.93\times10^{-4}$ at 12°, the solution being saturated with respect to $MgCO_3.3H_2O$, while for any temperature (t) up to 50° C., K_N is given by the formula $K_N=2315/(t+273)-11.870$. These results enable one to calculate the solubility of either of these substances at any partial pressure of carbon dioxide. The results of such calculations are tabulated in the original. In this connection it may be pointed out that there can be no real *equilibrium* in aqueous solutions of carbonates except in presence of a definite partial pressure of CO_2 in the atmosphere in contact with the solution—in other words, that, strictly speaking, we are dealing with a ternary system, namely, base–CO_2–H_2O; consequently any carbonate solution through which a stream of gas absolutely free from CO_2 is passed would gradually lose its carbonate and ultimately would contain only hydroxide.

With a knowledge of these constants and of the solubility-product constant of magnesium hydroxide, one can show that calcium carbonate precipitated from solutions containing magnesium is likely to be contaminated with small quantities of magnesium hydroxide which could be removed only slowly by re-precipitations as ordinarily carried out; that mixtures of magnesium carbonate and hydroxide will in general be obtained in the precipitation of magnesium by a carbonate and that the basic carbonates thus produced are merely indefinite mixtures of carbonate and hydroxide; and that both calcium and magnesium carbonates can be obtained free from contamination by keeping the partial pressure of carbon dioxide above a certain limiting value, the magnitude of which depends upon the conditions and in all probability need not be greater than 1 atm. by a suitable choice of mode of operation.

(23) On aventurine feldspar. Olaf Andersen. Am. J. Sci. (4), 40, 351–398 (1915).

In this investigation a number of varieties of aventurine feldspars were examined. Orientation angles of the reflecting lamellæ were measured, chiefly with the goniometer, and the properties of the lamellæ were determined under the microscope. Brief discussions of the optical problems are included in the record of these examinations.

The reflecting lamellæ are always oriented after simple crystal forms, of which (112), $(1\bar{1}2)$, (150), and $(1\bar{5}0)$ occurred as planes of orientation in all varieties, the first two causing aventurization on (001), the last two on (010). The forms (001), (010), (110), and $(1\bar{1}0)$ also frequently contain reflecting lamellæ. Exceptionally $(0\bar{2}1)$ and $(\bar{1}13)$ are planes of orientation. The orientation of the edges of the lamellæ was evidently regular, but simple crystallographic relations could not, in general, be found.

The reflecting lamellæ were determined as hematite. They vary widely from one variety to another as to shape and size, showing hexagonal, eight, or ten-sided, rhomb-shaped, strip-shaped, or irregular outlines. The largest measured 3.5 mm. in one direction, the smallest were of submicroscopic size. The absorption colors were those characteristic of hematite. It was shown that the colors in reflected light are interference colors of thin films. By means of these colors the thickness of the transparent lamellæ could be approximately determined. It was found to vary between 50 $\mu\mu$ and 500 $\mu\mu$. The lamellæ were shown to possess no appreciable pleochroism. The apparent pleochroism observed in lamellæ forming large angles with the section was found to be due to the effect of polarization by reflection and refraction at the surface of the lamellæ. The appearance of interference spectra in these lamellæ is due to the action of the lamellæ as polarizers or analyzers for the wedge-shaped parts of the feldspar that lie above or below them in the sections.

Thermal experiments with one of the varieties showed that the hematite lamellæ persist up to about 1235°. At this temperature they disappeared, presumably by melting together with a small part of the surrounding feldspar to thin, invisible glass films. The feldspar remained otherwise unchanged (crystallized). By heating at lower temperatures some of the lamellæ (the originally opaque ones) reappeared in the same places and with the same outlines as before. By a long heating at temperatures around 1050° (of cleavage pieces not previously heated) the opaque lamellæ generally became transparent and the others became a little lighter in color.

The origin of the hematite lamellæ was explained as due to unmixing of an originally homogeneous feldspar which contained iron oxides in solid solution. Thin lamellæ of hematite then separated along certain structural planes of the feldspar.

In the concluding section all the specimens examined are described and the measurements tabulated.

(24) Aventurine Feldspate. Olaf Andersen. Z. Kryst. (in press).

A German translation of "On aventurine feldspar" (Am. J. Sci. (4), 40, 351–398, 1915). Reviewed under No. 23 above.

(25) Der optische Charakter der schwachen, mit starken Objektiven zwischen gekreuzten Nicols beobachten Interferenzfigur. Fred. E. Wright. Z. Kryst., 55, 115–122 (1915).

A German translation of "The optical character of the faint interference figure observed in high-power objectives between crossed nicols" (J. Wash. Acad. Sci., 4, 301–309, 1914). Reviewed in Year Book No. 13, p. 147.

(26) Die thermale Entwässerung des Stilbit und Thaumasit; die Hydrate von Magnesium- und Kupfersulfat. H. E. Merwin. Z. Kryst., 55, 113–114 (1915).

A German translation of "The thermal dehydration of stilbite, thaumasite, and the hydrates of magnesium sulphate and of copper sulphate" (J. Wash. Acad. Sci., 4, 494–496, 1914). Reviewed in Year Book No. 13, p. 148.

(27) Die Messung der Brechungsexponenten mit dem petrographischen Mikroskop. Fred. E. Wright. Z. Kryst. (in press).

The petrographic microscope may well serve as an instrument for the measurement of refractive indices either of small drops of liquid or of minute crystal grains. In this article the more important of the various methods which have been suggested for this purpose are described briefly and with special reference to accuracy and ease of manipulation. The methods for measuring the refractive index of a liquid are based on one of the following factors: (*a*) The change in position of focus of the lens system on the introduction of a drop of liquid as an integral part of the lens system (methods of Piltschikow, Clay, Smith, Decombe, de Souza Brandao, and several new methods). These methods are in general accurate only to the second decimal place. Their weak feature is the difficulty of sharp focusing; this results chiefly from the disturbance of the corrections of the aberrations of the lens system on the introduction of the liquid as one of its components. (*b*) Direct comparison of the refractive index of one of a series of plates of crystals or of glasses of known refractive index with that of the liquid. (Methods of Michel-Lévy and of de Souza Brandao.) The chief difficulty in these methods is to obtain a sufficiently large series of crystal or glass plates, so that the intervals in refractive index are small. (*c*) Methods of total reflection. In this case the microscope serves as an instrument for measuring the inclination of transmitted light-waves, as in optic axial angle measurements. Five new methods based on this principle are described, of which the simplest and most convenient furnishes, under favorable conditions, refractive index values accurate to ± 0.001. The method of Wallérant requires the use of a special total refractometer attachment; although more accurate than any of the other methods, it has not come into general use because of the expense and trouble involved in making the measurements. (*d*) The method of Féry is also based on the phenomenon of total reflection, and is identical in principle with older methods in which the width of the circle or band of total reflection on either an immersed sphere or hemisphere of glass or a gas bubble serves as a measure of the relative refractive index of the adjacent liquid. This method is in general accurate to the second decimal place.

In the exact measurement of refractive indices of minute crystal particles by the immersion method, it is essential: (1) that correctly oriented sections be selected which are normal to at least one principal optic section; (2) that in case oblique illumination be used, only those pencils of light be employed whose direction of propagation is included in the plane normal to the principal optical section; in other words, the metal sliding strip should be so inserted that its front edge is parallel to a principal section; (3) that with central illumination special weight be given to the effects along those edges of the grain which trend approximately parallel to the principal section. If these conditions be disregarded the value obtained for the maximum refractive index will be too low, the value for the minimum refractive index too high, while that of any intermediate refractive index, as β, may be too high or too low. Failure to recognize these factors may lead, especially in the case of strongly birefracting crystal particles, to refractive index determinations which are appreciably in error.

(28) Pressure as a factor in the formation of rocks and minerals. John Johnston. J. Geol., 23, 730–747 (1915).

This is a brief general discussion of the available experimental evidence bearing upon the influence of pressure on melting and transformation points and solubility, and of the inferences with respect to the formation of rocks and minerals which may justifiably be drawn from this evidence. In general it would seem that the importance to geology of the effects of pressure upon so-called physical changes (*e. g.*, the melting-point of a single pure substance) has been overestimated relatively to that of the influence of pressure upon chemical changes—in other words, upon equilibrium in polycomponent systems. Change of effective pressure will in general change the configuration of the various fields of stability in a system, acting thus in a way precisely analogous to change of temperature, or of gross composition; but in the case of pressure the effect will usually not be especially marked unless one or more of the components is volatile; that is, unless the concentration of one or more of the components really changes appreciably with change of pressure. This is merely an example of the general rule that the magnitude of the effect of pressure on a system depends upon the difference in compressibility of the several phases present, being greatest when this difference is greatest, and conversely.

Accordingly we must, in any discussion of the course of crystallization from a complex magmatic system, take into account the mode in which the effective pressure varies as well as the mode of cooling. For change of pressure, like change of temperature, may affect the order of crystallization, and even the character of the minerals which separate, this result of course depending merely upon the circumstance that the saturation limits (solubilities) of the several solid phases which could possibly separate out are not all affected equally by change of conditions.

(29) Druck als ein Faktor der Mineral- und Gesteinsbildung. John Johnston. Neues Jahr. Min. Geol., II, 89–108, 1915.

A German translation of "Pressure as a factor in the formation of rocks and minerals" (J. Geol., in press). Reviewed under No. 28 above.

(30) The sulphides of copper. Eugen Posnjak and E. T. Allen (thermal and chemical study); H. E. Merwin (microscopic study). Econ. Geol., 10, 491–535.

Cuprous sulphide was prepared in a vacuum furnace and its melting-point determined therein; the latter was found to be $1130° \pm 1°$. No dissociation of cuprous sulphide takes place at 1200°. The specific gravity of synthetic cuprous sulphide, $\frac{\text{substance } 25°}{\text{water } 4°}$, was found to be 5.785; practically the same as the specific gravity of the purest natural mineral analyzed, viz, 5.783, $\frac{\text{mineral } 25°}{\text{water } 4°}$.

The copper sulphides obtained by fusing together copper and sulphur are of variable composition and always contain more sulphur than the ratio 2Cu : S. They are microscopically homogeneous and vary continuously both in color and in specific gravity with composition; as the sulphur increases they become darker in color and lighter in gravity. The specific volumes of these products lie within the limits of error on the straight line connecting the specific volumes of cuprous and cupric sulphide. It has been shown that these products are solid solutions of cuprous and cupric sulphide.

Copper sulphide melts in an atmosphere of hydrogen sulphide at 1096°; in an atmosphere of sulphur vapor at 1057°. The lower melting-point as compared with that of cuprous sulphide is due to dissolved cupric sulphide, which increases with the increase of the sulphur-vapor pressure surrounding it.

When cuprous sulphide is heated in an atmosphere of hydrogen sulphide at various temperatures (below the melting-point), its sulphur content increases. For each temperature the products contain a definite amount of sulphur. This sulphur content increases with the decrease in temperature until at 358° the product becomes cupric sulphide.

Solid solutions of cuprous-cupric sulphide were also prepared by heating compressed powders of the two sulphides at about 100°.

The analyses of a number of natural chalcocites from widely varying localities proved that solid solutions sometimes occur in nature. The geological significance of this fact is yet to be discovered.

Cuprous sulphide is dimorphous. The inversion temperature was found at about 90°. No other inversion could be detected either by the thermal or by the conductivity method. It has been shown that the size of the grains considerably influences the inversion temperature.

Increasing amounts of cupric sulphide, dissolved in cuprous sulphide, raise the inversion temperature. This takes place until cupric sulphide reaches the concentration of about 8 per cent, after which an inversion is no longer observed.

Crystals of chalcocite were repeatedly formed in the dry way at various temperatures, but only above about 250° were they large enough to permit the determination of their symmetry; all these crystals were isometric.

Isometric crystals of cuprous sulphide were also obtained from solutions at 250° by the reaction of cuprous chloride with sodium sulphide and at 200° and 170° by recrystallization of cuprous sulphide in solutions of hydrogen sulphide. Very small crystals, apparently cubo-octahedrons, were also found at 125°.

Crystals formed by the action of ammonium sulphide on copper, repeatedly described in the literature as orthorhombic cuprous sulphide, have in reality the composition $Cu_7(NH_4)S_4$. A crystallographic study showed that they are not orthorhombic, but tetragonal.

Observations of cleavage and parting, combined with a knowledge of the effect of dissolved cupric sulphide on the inversion of cuprous sulphide, are applied to the problem of distinguishing primary from secondary chalcocite ore.

The possible bearing of some of the data on the origin of chalcocite ores is a matter of much interest.

Covellite has been prepared in many different ways and a crystallographic and optical study of it made. It is hexagonal and optically negative; the optical dispersion of ω is extremely high. $\omega_{Li} < 1.0$, $\omega_{Na} = 1.45$, $\omega_{Tl} = 1.75$.

The specific gravity of two very pure samples of natural covellite has been determined and found to be 4.683 and 4.676 respectively $\left(\frac{\text{mineral } 25°}{\text{water } 4°}\right)$. This specific gravity is higher than any previously given. The specific gravity of synthetic covellite varied with the fineness of the material used. This was probably due to occlusion of air by aggregates of very fine crystals. The highest value obtained with synthetic covellite was 4.652 $\left(\frac{\text{substance } 25°}{\text{water } 4°}\right)$.

Covellite can be heated in an atmosphere of hydrogen sulphide up to 358°; at which temperature the covellite is in equilibrium with the gas, and below it chalcocite can be completely converted into covellite.

(31) Die Kupfersulfiden. Eugen Posnjak und E. T. Allen (thermochemische Untersuchungen), H. E. Merwin (mikroskopische Untersuchungen). Z. anorg. Chem. (in press).

A German translation of "The sulphides of copper" (Econ. Geol. 10, 491–535, 1915). Reviewed under No. 30 above.

(32) The dissociation of calcium carbonate below 500°. R. B. Sosman, J. C. Hostetter, and H. E. Merwin. J. Wash. Acad. Sci., 5, 563–569 (1915).

Pure lime, CaO, is obtainable in two forms. The first, which is probably amorphous, results from the dissociation of $CaCO_3$ at low red temperatures. On heating for a considerable time at higher temperatures, it changes gradually into the cubic crystalline lime of refractive index 1.83. The latter forms directly from silicate melts or from fused calcium nitrate, and is the stable form at high temperatures. There are indications that it has an inversion-point (perhaps similar to the inversion between high- and low-temperature quartz) between 400° and 430°.

The porous lime unites very readily with dry carbon dioxide, and the compound dissociates readily with rising temperature. The crystalline lime unites very slowly with dry carbon dioxide. The crystalline forms of calcium carbonate dissociate very slowly at low temperatures, and the rate does not seem to be hastened by the presence of Fe_2O_3 or of CaO. Aragonite is transformed into calcite within an hour at 425° in the vacuum furnace. The dissociation pressures of crystalline calcium carbonate at 400° are of the order of magnitude of 0.003 to 0.009 mm.

(33) The constituents of portland cement clinker. G. A. Rankin. Concrete-Cement Age, 6, 55–63 (1915).

Reprinted from "The constitution of portland cement clinker" (J. Ind. Eng. Chem., 7, 466–474, 1915). Reviewed under No. 17 above.

(34) Present condition of the volcanoes of Southern Italy. H. S. Washington and Arthur L. Day. Bull. Geol. Soc. Am., 26, 375–388 (1915).

The volcanoes Vesuvius, Etna, Vulcano, and Stromboli were visited in the summer of 1913 and their condition of activity at that time described. Vesuvius showed signs of a renewal of activity, which was to be expected after the exceptionally long interval of repose since the last great eruption of 1906. A descent to the bottom of the crater was made in June, which permitted some detailed observations at the active vent. Etna was found to be in a moderately active condition, with minor solfataric and strombolian outbursts. The large bocca of 1911 has greatly increased in diameter. It appears to be eating its way into the main crater, and it is probable that when this happens an eruption may be expected. Stromboli was in its normal active condition. Five vents in the crater were observed, each differing from the others in the character of its activity. Vulcano was in the same solfataric condition which has prevailed since the last eruption in 1888–89.

Many samples of gases and salts were collected, especially at Etna and Vulcano, which are now being investigated. It is noteworthy that, at Vulcano, the salts are practically free from chlorides, and that the amount of boric acid has greatly decreased since the last eruption. A large collection of rocks from all the volcanoes was also made, which are to be studied later.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the tenth annual report of the present Director, covers the period from November 1, 1914, to October 31, 1915. The regular staff of the Department has continued without change during the year. Rear-Admiral Alfred T. Mahan, U. S. N., retired, began on November 1, 1914, a term of assistance to the Department in the capacity of Research Associate, which was intended to continue for six months, but which was cut short at the end of one month by his death. The exciting events of the great European war had greatly affected his health, and his constitution was no longer as strong as in earlier periods of his life. He therefore came to the service of the Institution a sick man and was able to render to the Department only a part of the service which he had hoped to perform when, in a better state of health, he had made his engagement with the Institution. Nevertheless, such were the directness, lucidity, and force of his mind and the value and stimulating quality of the thoughts set forth in his books and in his few lectures to the staff, that he left upon the Department an impress which will have long-continued effects, while the obvious nobility of his character and the charm of his conversation, endearing him to all members of the staff, left with them a memory which will always be treasured.

Professor R. H. Whitbeck, of the University of Wisconsin, on leave of absence from his university, began in October 1914 a period of assistance to the Department, which terminated early in February 1915. Professor Frank A. Golder, of the Washington State College, who had been employed for the Department in Petrograd and Moscow, left the former city in the middle of November 1914 and, with considerable difficulty, made his way back by way of Siberia to Washington, where he worked for some months in the offices of the Department.

The Department has continued to occupy the same quarters as in preceding years, in the Woodward Building in Washington. The usual removal of headquarters to Maine in the middle of June did not take place. The Director went at that time to California, where he attended the meeting of the American Historical Association, and by this and other means increased his acquaintance and scientific relations with the members of the historical profession resident in the western half of the United States. For a month after his return, in the middle of August, that portion of the work of the Department which is most immediately under his care was carried on, with the assistance of a part of the staff, at Grand Isle, Vermont. Since the

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latter part of September all the Department's work has once more been concentrated at the offices in Washington.

The main purpose of the Department, as set forth in former reports, is, briefly expressed, to serve the interests of present and future makers of historical monographs and general histories, by providing aids belonging to one or the other of two main classes—either books which show the inquirer the existence and location, or assist him in the use, of bodies of historical sources, or books which themselves present in proper scientific form the full text of important historical materials. Thus the publications of the Department fall naturally in two classes: the one that of reports, aids, and guides; the other that of textual publications of documents. It has been customary in these annual reports to consider, successively, first the work of the past year, in respect to each of these two classes of publications and in respect to the miscellaneous activities of the Department, and then the plans for the ensuing year, under the same three headings.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

No volumes have been published for the Department during the year, but four manuscripts have been completed.

A Guide to the Materials for American History in the archives of Switzerland and Austria went to the printer in July; most of the galley-proofs have been received. In this book, as was explained in the last report of the Department, the main portions, relating to the archives of German Switzerland and Austria, were prepared by Professor Albert B. Faust, of Cornell University, after extensive investigation in these archives. The small portion relating to the archives of the French cantons of Switzerland rests upon investigations made by the Director of the Department. The volume will make about 300 pages and will furnish useful guidance to all students of the history of Swiss and Austrian emigration to the United States and of the diplomatic relations between the United States and those countries.

Mr. R. R. Hill's Descriptive Catalogue of the Materials for United States History in that section of the archives of the Indies which is called "Papeles procedentes de la Isla de Cuba," fully described in the last report of the Department, was then stated to have been finished in manuscript. The manuscript, however, remained for some time in Mr. Hill's hands, in order that the main portions of the work of making the index, which will refer to *legajos* rather than to pages of the printed book, might be performed by him. The many variations in the spelling of proper names, and the consequent difficulty of identifying persons, made it expedient that this work should be done by one having Mr. Hill's familiarity with the subject-matter, rather than by an ordinary

indexer. Since the receipt of the manuscript at the office of the Department, it has undergone its final preparations for publication, and has recently gone to the printer.

On returning from Russia, by the difficult journey alluded to above, Professor Frank A. Golder brought with him safely the manuscript notes for his Guide to the Materials for American History in the Archives of Russia. During the period which he spent in Washington after his return, he prepared from these notes the manuscript of his volume, a book which will apparently amount to 150 or 200 pages of print, rich in information respecting the history of diplomatic relations between the United States and Russia and of the explorations and settlements of Russia in northwestern America. This manuscript will shortly be made ready for publication.

The fourth manuscript alluded to, that of Miss Davenport upon European treaties relating to America, is more fittingly described in the next section of this report.

The arrangements which Mr. W. G. Leland, on leaving Paris in September 1914, had made for continuing in the French archives, during his absence, the work of research toward his Guide to Materials for American History to be found there, had to be canceled in the winter because of the unsatisfactory conditions prevailing in those archives and the difficulty of securing anyone competent to undertake general supervision of the work. The archives of the Foreign Office have remained closed throughout the year; until they reopen, it will be impossible to complete the work of the Guide. Monsieur Abel Doysié, who had so efficiently aided Mr. Leland for several years past, is now in the army, and other members of the staff employed by Mr. Leland when in Paris have been scattered by the events of the war. Except for the obtaining of notes on certain portions of the archives of the Ministry of Marine, through the courtesy of Mr. H. P. Biggar, agent of the Canadian government, little has been done in Paris. Meanwhile, Mr. Leland's notes, the fruits of several years' labor, arrived safely in America, by reason of careful precautions and arrangements made by him. Since their arrival he has spent a considerable amount of time in arranging and cataloguing them, endeavoring to do what could be done toward completing the manuscript while awaiting the conclusion of the war. That event alone can bring an opportunity to do in Paris the relatively small amount of work which had not been finished before the outbreak of hostilities.

A year ago it was reported that Dr. Francis S. Philbrick had made, in the Archives of the Indies, at Seville, all the necessary arrangements for the making of a series of 2,000 photographs, from a certain series of Louisiana documents preserved there. The photographs were to be made in the archives by a firm of photographers in Seville. Paper for the negatives, delayed by the outbreak of the war, reached Seville

at about the time of Dr. Philbrick's departure. But his designations had been made upon so systematic a plan that it was found possible to carry forward the work of photographing after his return. This the Department has been able to secure through the kind offices of Mrs. Adolph Bandelier. Remaining in Seville since the death of her husband, and occupied in part in completing the work upon which he had been engaged under a grant from the Carnegie Institution of Washington, Mrs. Bandelier kindly undertook for this Department the supervision of this work of photography. With some expansion of the plan as first formed, negatives to the number of somewhat more than 2,500 have been made by the Seville photographer. These have been shipped in small quantities to Paris, where prints, extremely satisfactory in character, have been made from them by a reliable photographer, Monsieur Louis Doysié. These prints have been shipped to Washington. When the present work in Seville and Paris is brought to an end, soon after the date of this report, by the return of Mrs. Bandelier to the United States, the prints in the hands of the Department will represent the regular series of official civil dispatches sent by the Spanish governor of Louisiana to the Captain General at Havana, from the beginning of the Spanish régime in New Orleans in 1768 to the arrival of Carondelet as governor, at the beginning of 1792. Ten prints have been made from each negative, and ten series of photographs will shortly be available for any subscribers who may desire to purchase the series at cost.

In the work for the proposed Atlas of the Historical Geography of the United States, Dr. Charles O. Paullin, with some clerical assistance, has completed the sketches for two divisions of the Atlas; that which illustrates the history of presidential elections—by plotting, by counties, plurality votes for presidential candidates, and that which exhibits, by Congressional districts, the votes cast in the House of Representatives for or against each one of a selected series of thirty-two important typical measures of national legislation, extending over the period from 1789 to 1915. The maps, in suitable form for execution by photolithography, have been prepared from these sketches by Mr. J. B. Bronson, of the Navy Department. Dr. Paullin has completed the extensive letter-press explanations which will accompany the maps he has thus far made.

Meanwhile, a large part of the work of preparing certain other sections of the Atlas has been accomplished by Professor R. H. Whitbeck, professor of geography in the University of Wisconsin. During his residence with the Department in Washington he prepared a general base-map, showing contours and elevations, which will underlie many of the maps showing industrial and other economic features of American history, and elaborated maps showing features of physical geography, soil and climate, mineral deposits, typical crops, and the development

of selected industries, during various periods of American history. During the summer, at Madison, he nearly completed the series of maps showing the growth, in successive decades, of railroad and other lines of transportation. A large map, showing oceanographic data related to American history, has been prepared for the Department by Mr. G. W. Littlehales, of the Hydrographic Office in the Navy Department. Arrangements have been made for the speedy securing of an adequate map of the geology of the United States, containing the results of the most recent researches, and of a series of maps, prepared under official auspices, exhibiting densities of population at the time of each United States census.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

The first volume of Dr. Frances G. Davenport's collection of "Treaties between European powers, relating to American history," extending through the treaties of 1648, has been completed in manuscript, so far as her own work is concerned, and will shortly be made ready in all respects for printing. Beginning with the papal bulls of the fifteenth century relating to America, documents having an international character analogous to that of treaties, this work presents, as its main substance, the texts of all those European treaties or parts of treaties which have a bearing upon the history of America. These texts, usually printed with considerable inaccuracy, and for the most part to be found only in expensive printed collections, or in some cases only in manuscript, have for the purposes of the present work been prepared by careful collation of the original manuscript ratifications in various European archives. Careful introductions to each document explain its relation to the history of America, and trace the gradual development of European policy respecting the New World. Proper annotations and lists of bibliographical references accompany each document.

The volumes of "Letters of delegates to the Continental Congress" have received some augmentation in text from the addition of letters which have come to light during the year. Especial thanks are due to Mr. George S. Godard, Librarian of the Connecticut State Library, and to the owners of the Joseph Trumbull Collection, recently deposited in that institution, for the opportunity to take additional texts from that collection. The main work of the last year has been that of annotation, by Dr. E. C. Burnett, who has completed this process to the end of the year 1776.

In respect to the series of "Proceedings and Debates of Parliament respecting North America, from 1585 to 1783," the journals of the Irish House of Lords have been searched to 1783 and the appropriate entries selected, by Mr. L. F. Stock, editor of this series. The copying of the selected items from the journals of the Irish House of Commons has been finished. Thus that part of the text which consists of par-

liamentary proceedings has been brought almost to its conclusion, the chief exception being the proceedings of the Scottish Parliament. In respect to that portion of the work which will consist of parliamentary debates, the examination of materials and the selection of texts has been finished to 1750, and a beginning of the work of copying them has been made. We have received a considerable body of transcripts of notes, found in the French archives, reporting debates in the British Parliament bearing upon American affairs. These reports, secretly sent from London for the benefit of the French Foreign Office, make an important addition to the known record of British debates on America, especially at times when publication of parliamentary reports in England was obstructed.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department, and by its staff. Aid has been given, in a number of ways, to the American Historical Association, of which Mr. Leland is secretary. Miss Donnan has finished editing, for the Historical Manuscripts Commission of that society, the papers of the elder James A. Bayard, and the volume has been published as volume II of the Society's Annual Report for 1913. Mr. Leland has continued to render aid to the State of Illinois and to various societies, in respect to materials from the archives of Paris, so far as conditions in these archives have permitted. He has also directed the making, in Paris, of an extensive series of copies of historical manuscripts for the Library of Congress, work which, after interruption for some months early in the year, is now again progressing. With some assistance from Dr. Burnett, he has edited a collection of letters from Lafayette to Luzerne, which he found in the archives of the Ministry of Foreign Affairs in Paris and which have been printed in the *American Historical Review*.

As in previous years, searches and copies have been made, in Washington, by the Department, or under its supervision, for various historical societies and for many individuals. To perform such services, and to answer the numerous letters of inquiry received as to historical papers in Washington, and similar matters, consumes no small amount of time; but it has always been held to be a part of the functions of the Department to further the interests, in Washington, of all American historical scholars, and to mediate between them and the various archives in Washington, or in foreign countries, whenever occasion has arisen. Until a suitable National Archive Building has been erected in Washington, an end toward which Mr. Leland and the Director have expended much earnest effort, it will always be difficult for persons at a distance to know where any given paper of historical importance is likely to be found, or what bureau or official to address in order to

secure a copy of it. It is often possible for the Department to answer such questions off-hand, out of the knowledge of various archives which individual members of its staff have acquired. In other cases, it is the practice of the Department to pursue such inquiries freely for all institutions or scholars whose objects have any historical importance, unless the inquiry proves to take more time than can be afforded without detriment to the regular occupations of the members of the staff. In these cases of more extensive inquiry, and in respect to requests for copying, it is the custom of the Department to place all such orders in the hands of persons professionally occupied with such work, and to whose competence the Director can certify.

PLANS FOR 1916.

REPORTS, AIDS, AND GUIDES.

The first work of the Department for the year beginning November 1, 1915, under this head, should be the issue of Mr. Faust's Guide to the Materials for American History in Swiss and Austrian Archives, of Mr. Golder's report on similar materials in the archives of Russia, and of Mr. Hill's Descriptive Catalogue of the Papers concerning United States History in the "Papeles de Cuba" of the Archives of the Indies. Upon the completion of prints from the series of photographic negatives made in that archive, and the reception of the final installments of them, the whole mass will be arranged in sets, with appropriate lists and explanations, and offered for sale at cost, to institutions which have manifested an interest in the series, and to others.

Mr. Leland's main work will consist in doing all that can be done, before the end of the European war makes possible his final expedition to Paris, to reduce the notes already taken into as close an approach as is possible to their final form as a report adapted to publication.

It is not expedient to undertake any large piece of work in European archives till after the close of the war. In the belligerent countries, satisfactory work of this sort is in most cases impossible. Even in the neutral countries of Europe, conditions are such that later times will surely be better for our purposes. Archive staffs are disorganized or are working under unusual disadvantages. Important as is the place which the furnishing of guidance to American materials in European archives has held and still holds in the Department's scheme of operations, it so happens that the most pressing tasks in the first division of that scheme, the making of general surveys, has been completed in all the most urgent instances except that of Paris. It is possible to make a pause without great damage, and to resume the work when it can be taken up under more favorable auspices. In the meantime, it would be possible, whenever suitable appropriations for the purpose could properly be made, to continue work of this same variety in a region not

seriously affected by the war, namely, in the British and French West Indies. Guides to materials for United States History in the archives of Canada, Mexico, and Cuba have already been published. The archives of the British West Indian Islands, while in some respects duplicating the Colonial Office papers in the Public Record Office of Great Britain, contain, nevertheless, a very large amount of material, capable of illustrating the history of the United States in two ways. In the first place, it has been too much a habit of writers upon the colonial period of United States history to confine their attention to the thirteen colonies which subsequently formed the United States of America. This is to read into the history of the seventeenth and eighteenth centuries distinctions which did not then exist. An important corrective to colonial constitutional history and to the history of British administration of the mainland colonies, is to be obtained by close study of the history of the island colonies, and of the British colonial administration in an extent embracing the whole of the early British colonial empire, continental and insular portions alike. In the second place, commerce between the West Indies and the Americans of the mainland, in the colonial period and in at least the first thirty years after the Revolution, had so large a place in the economic life of the United States that its illustration by materials from the island archives is highly desirable. The archives of the French West Indies, and specifically of Martinique and Guadeloupe, may have importance for American commercial history on similar grounds—an importance better measured by the debates of 1760–1761 as to whether Great Britain should retain Canada or Guadeloupe than by any estimates based on conditions now. Of the archives of Bermuda and the Bahamas, much the same things may be said as of those of the British West Indies. Taken together, these islands present an opportunity for a useful volume, having its appropriate place in our series. The main portion of the work could be undertaken in either 1916 or 1917 by Professor Herbert C. Bell, of Bowdoin College, a specialist in the history of the British West Indies.

It is to be expected that work on the Atlas of the Historical Geography of the United States, under Dr. Paullin's general direction, will during the year be advanced in many particulars. Precisely which sections will be finished during the year it is impossible to predict, since much depends upon the opportunities secured from time to time to obtain the aid of persons having special historical or geographical acquirements relating to this or that portion of the work, but who have regular occupations not leaving them continuously free for assistance to the work of the Department.

TEXTS.

The annotation of the "Letters of Delegates to the Continental Congress" becomes a somewhat easier matter after 1776. Dr. Burnett, expending as large a part of his time as is possible upon this

process, will expect to make great progress in it during the course of the year. Miss Davenport will give all of her time to the second volume of her book of treaties, extending from the conclusion of the Treaties of Westphalia in 1648 to 1713, the year of the Treaties of Utrecht. Mr. Stock will carry down, from 1750 towards 1783, as far as is possible within the year, the collection and editing of texts of the Parliamentary Debates respecting America.

MISCELLANEOUS OPERATIONS.

The Department will no doubt maintain, in 1916, activities similar to those which, under this heading, have been described above in that part of this report which relates to the last twelve months.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYER, DIRECTOR.

Under existing conditions it has seemed best to defer the taking of definite steps leading to the transfer of our main laboratory from the Tortugas to some more accessible place in the West Indian region in which a station of international scope could be established. At present, however, the station is operated at some disadvantage. Our sole contact with Key West, distant 68 miles, must be maintained by weekly trips made with the *Anton Dohrn* at a cost of nearly $150 for each such voyage. Moreover, this periodic interruption of the scientific work which the yacht itself should perform has largely prevented our using this excellent little vessel for the oceanographic studies for the prosecution of which she is so well fitted. Our activities have therefore been in a measure restricted to researches in physiology, ecology, and experimental fields, the material for the prosecution of which could be obtained in the near neighborhood of the laboratory and without the use of the *Anton Dohrn*. With numerous local oceanographic problems awaiting solution, it is to be regretted that we have heretofore been unable to enter upon sustained and intensive work in this field.

It is, however, of primary importance that we should determine upon the best possible site in the whole West Indian region in which to place our new laboratory should the abandonment of the Tortugas become necessary. The Director, therefore, during March and April 1915, visited St. Thomas, St. Croix, Guadeloupe, Dominica, Martinique, St. Lucia, Montserrat, St. Christopher, Barbados, and Demerara. Data which will be of value in determining the proper sites for stations for special studies were obtained; rich coral reefs were found in places, and we observed the remarkable pelagic life of the northern branch of the Great Equatorial current which runs along the northern coast of South America beyond the region of the muddy shore-waters heavy with silt from the great rivers.

This observational cruise was supplemented in May by an expedition to Porto Rico. upon which the Director was accompanied by Professors Edwin G. Conklin, A. J. Goldfarb, John H. Gerould, William H. Longley, C. F. Silvester, and A. L. Treadwell, while Mr. Stanley J. Rowland served as artist and Mr. John Mills as engineer. The expedition was designed to test the availability of Porto Rico as a site for an international marine laboratory of research. Following the advice of Professor Henry E. Crampton, who did all in his power to aid us, we made Guanica Harbor our chief objective, although studies were also conducted at Condado Bay near San Juan.

*Situated at Tortugas, Florida.

At Ensenada, on the shore of Guanica Bay, we were most kindly received and comfortably housed by the officers of the great sugar estate of Guanica Centrale. Especially is our expression of gratitude due to Mr. F. T. Maxwell, vice-president and general manager of the Guanica Centrale, who, with characteristic energy, intelligence, and interest seemed to forestall all our wants and rendered our visit a pleasure which none of us can forget. The attitude of this gentleman was, however, but a major instance which was supplemented by the reception we were accorded by His Excellency the Governor, and by Major Dutcher, Messrs. Sanborn, Smyth, George D. Graves, and others who contributed in many ways to facilitate our work, as when Mr. Alejandro Franceschi, of Yauco, generously offered to place at our service, for laboratory purposes, his house at Ballena Point.

The fact that a great future is assured to Porto Rico renders it desirable that if possible an international marine laboratory, under American auspices, should be established in this growing American colony. It is, however, unfortunate that the limestones of Porto Rico are in most places elevated above the shore-line, leaving the harbor bottoms and the strand covered with rocks that break up into fine mud, which, owing to the absence of strong tides, becomes charged with sulphureted hydrogen and with carbon dioxide, due to the decomposition of animal and vegetable matter. Thus we met with failure in all those studies wherein it was necessary that animals be maintained alive in laboratory aquaria, this being true not only at Guanica but also in Condado Bay, in which one finds a remarkably rich and varied fauna of fishes, echini, worms (*Cerebratulus*), and medusæ (*Cassiopea*). The coral reefs of the off-lying limestone islands are rich, but close along the shores of Porto Rico there are relatively few corals. The deleterious influence of Guanica Harbor is well shown where the coral reef to the westward of the entrance is largely killed by the water which, issuing from the harbor, is drifted along the shore by the prevailing wind. The *Acropora* are nearly all killed, while members of the genus *Porites* have suffered more or less, and *Favia* and *Siderastrea* have survived without apparent injury. Thus the corals suffer in proportion as they are unable to withstand the presence of carbon dioxide in the water.

It thus appears that Porto Rico is surpassed by Jamaica as a site for an international marine laboratory. Owing to these conditions, the projected studies of Conklin, Goldfarb, and Mayer, which depended for their success upon the purity of the water, failed to a greater or less degree, whereas the other members of the expedition met with a good measure of success. Thus Professor Gerould, who came to continue in the tropics the notable breeding experiments with butterflies which he has for years conducted upon New England forms, collected the eggs of various species of the Pieridæ which were abundant in Porto

Rico and which constitute favorable material for his studies. In these investigations he enjoyed the facilities afforded him by Mr. Eugene G. Smyth, of Santa Rita.

With characteristic energy Professor W. H. Longley spent hours observing the habits and coloration of the reef fishes and obtaining additional facts to support the great weight of evidence he has already gathered which demonstrates that in numerous instances the habits of fishes are such as to enhance the inconspicuousness of their colors; thus protective coloration is a factor of primary importance, which has been acquired in a great variety of ways by the fishes of the transparent waters of the coral reefs. The efficacy of Abbott H. Thayer's scheme of color pattern in securing protection is strikingly illustrated in many instances, and at a time when the Darwinian theory of natural selection seems undermined and weakened by the revelation of the importance of de Vriesian mutation, this research of Professor Longley acquires a peculiar and timely interest. His studies at Porto Rico were continued during June and July at Tortugas, where he made use of a diving-hood recently invented by Mr. Dunn of Miami, which enabled him to remain under water for indefinite periods of time. Several years must elapse before Professor Longley's researches can be properly published, but next year he should be provided with special equipment, such as under-water camera, glass-bottomed boat, and diving apparatus, and above all with the services of a competent artist.

Dr. C. F. Silvester made a special collection of Porto Rican fresh and salt water fishes for systematic study, finding more than 100 species, 7 being new to science; and he also gathered invertebrates for the museum at Guyot Hall, Princeton University, corals for the National Museum in Washington, and fishes from Porto Rican caves.

Professor A. L. Treadwell was assisted by Mr. Stanley J. Rowland in Porto Rico, and by Mr. Rudolph Weber in Tortugas, who served as artists in illustrating the Leodicidæ, to the study of which group Professor Treadwell has devoted a number of years. He determined that the Atlantic palolo swarmed at Tortugas on July 1, 1915.

It is perhaps unfortunate that the absorbing interest which the experimental side of biology has in recent years attracted to itself should have cut down activity in systematic work. Yet there is still a wide field for the production of such beautiful and valuable papers as constituted the early volumes of the "Naples Monographs," and the laboratory would be remiss in its duty did it neglect the opportunity to afford facilities to competent students for carrying out work of this character.

If we are to achieve success in studies of the hereditary traits or physiological reactions of animals, it is fundamentally essential that we should know the anatomy and relationships of the forms we work with, yet our knowledge of such matters remains in many respects

sadly incomplete. Nor does the systematic study of a group blind us to the opportunity it affords for experimentation, for indeed among our ablest experimenters are those who began their scientific work as systematists.

The Laboratory has been criticized for the apparently aimless and heterogeneous character of its research work, but in such matters we are forced in some measure to be opportunists. Wherever a problem appears and a preeminently competent man can be obtained to attempt its solution, we deem it our privilege and indeed our special function to extend to him the opportunities afforded by the Tortugas.

Certain problems can be attacked at Tortugas as nowhere else in the world at present. Such are those of the coral reefs, of the habits and color of reef fishes, the analysis of tropical sea-water, the formation and solution of limestones in a tropical area, and, above all, physiological experiments of a difficult sort can here be performed, due to the purity and reliability of the sea-water, free as it is from contamination due to man. We are, moreover, fortunate in having in abundance the scyphomedusa *Cassiopea xamachana*, a truly remarkable animal for experimental studies. Thus, while to a superficial view our researches may seem varied to the degree of being aimless, yet each one has been of a character for the study of which the Tortugas has afforded a peculiar advantage; our investigations have aimed to reveal the underlying laws which control the vital processes of the marine animals of the tropics, and the illuminating studies by Vaughan and Drew of the geologic and organic processes which have given rise to the limestones of Florida have revolutionized our conception of the geologic importance of coral reefs.

The Laboratory studiously avoids encouraging work which may as well be done elsewhere. It is our aim to extend and to supplement the efforts of other institutions and in no sense to become the rival of any. For the sake of progress, we must augment, not duplicate, research. If a field of research is adequately covered by existing agencies, the Laboratory, as a department of the Carnegie Institution of Washington, has every reason to refrain from entering it, and this, of itself, must make our choice of subjects appear both arbitrary and undirected to those who have not fully appreciated the conditions under which we labor.

INVESTIGATORS.

In addition to the Director, 21 investigators studied under the auspices of the Department of Marine Biology during the past year, the list being as follows:

Name.	Place and time of study.	Subject.
Paul Bartsch, U. S. Nat. Mus.	June 17 to 30, Tortugas......	Hereditary variations of Cerions transplanted to Florida from the Bahamas.
H. H. M. Bowman, University of Pennsylvania.	June 1 to Aug. 2, Key West and Tortugas.	Growth, ecology, and physiology of mangroves.
E. G. Conklin, Princeton University.	May 20 to 28, Porto Rico.	
Ulric Dahlgren, Princeton University.	Hampton Roads, Virginia.....	Development and philogeny of electrogenic tissues in fishes.
J. H. Gerould, Dartmouth College.	May 20 to June 16, Porto Rico.	Heredity in Lepidoptera.
A. J. Goldfarb, College of City of New York.	May 20 to Aug. 2, Porto Rico and Tortugas.	Chemistry of fertilization in Echini. Effects of CO_2 on regeneration in *Cassiopea*.
E. W. Gudger, State Normal College, North Carolina.	June 12 to July 15, Key West and Tortugas.	Anatomy of sharks.
E. Newton Harvey, Princeton University.	June to July, Cuba.........	Chemistry of luminous substances in animals.
W. H. Longley, Goucher College, Baltimore.	May 20 to Aug. 2, Porto Rico and Tortugas.	Relation between coloration and habits in fishes.
George Matthai, B. A., Emmanuel College, Cambridge University.	July 15 to Aug. 10, Tortugas–Florida Reef.	Development, relationships, and growth of corals.
A. G. Mayer, Carnegie Institution of Washington.	Mar. 27 to Aug. 2, West Indies, Porto Rico, and Tortugas.	Chemistry of nerve conduction. Solution of limestone in sea-water. Reactions of corals to low temperatures.
Edwin E. Reinke, Vanderbilt University.	July 2 to 24, Tortugas.......	Physiological reactions of molluscan spermatozoa.
E. W. Shaw, U. S. Geological Survey.	July 15 to Aug. 10, Tortugas–Florida Reef.	Physiography of limestone region of southern Florida.
C. F. Silvester, Princeton University.	May 20 to June 16, Porto Rico.	Fishes of Porto Rico.
Shiro Tashiro, Chicago University.	July 2 to Aug. 2, Tortugas....	Effects of nervous system upon metabolism. Condition of the CO_2 of sea-water.
A. L. Treadwell, Vassar College.	May 20 to Aug. 2, Porto Rico and Tortugas.	Leodicidæ of the West Indies.
Gilbert van Ingen and A. H. Phillips, Princeton University.	July 2 to 24, Tortugas......	Heavy metals in marine invertebrates.
T. W. Vaughan, U. S. Geological Survey.	July 15 to Aug. 10, Tortugas–Florida Reef.	Geology of southern Florida. Growth rate of corals.
John C. Waller, B. A., Cambridge University.	July 2 to Aug. 2, Tortugas....	Electrical responses of plants.
E. I. Werber, Yale University.	Princeton University and Woods Hole.	Experimental control of development in fishes.

Mr. Stanley J. Rowland served as artist in Porto Rico from May 20 to June 7 and Mr. Rudolph Weber in a similar capacity during the month of July at Tortugas, both being engaged in making drawings of annelids to illustrate Professor Treadwell's research upon the Leodicidæ of the West Indian region.

The Tortugas surpasses all other marine stations in the purity of its ocean water, in the nearness of its coral reefs, and in having in *Cassiopea* a cœlenterate unmatched as an object for experimental studies. Accordingly, the efforts of a group of students at Tortugas have this year been directed toward acquiring a fuller knowledge of the nature of the chemical equilibrium of the CO_2 of sea-water and of the effects of this agent upon growth, regeneration, and the rate of nerve conduction in *Cassiopea*.

Dr. Shiro Tashiro devised a method which demonstrates that although sea-water is normally alkaline, yet it contains a substance, probably free CO_2, which dissolves calcium carbonate. In confirmation of this Mayer showed, as a result of placing shells in sea-water for one year, that calcium carbonate is dissolved at a slow rate by sea-water which, during the process of solution, remains alkaline. The rate of this solution is, however, so slow that it would require at least 1,000,000 years to dissolve off a thickness of 6 feet of calcium carbonate, and as most lagoons are about 20 fathoms deep and are geologically of recent formation, they can not have been dissolved out by sea-water as such.

A weak concentration of the H ion of free CO_2 is a powerful stimulant augmenting the rate of nerve conduction in *Cassiopea*, whereas in higher concentrations, the hydrogen ion becomes a depressant. Thus, if sea-water be slightly diluted with distilled water which contains carbon dioxide, it acts as a stimulant which augments the rate of nerve conduction above the normal, despite the reduction in concentration of sodium, calcium, and potassium. It is thus essential that the distilled water should contain no greater concentration of free CO_2 than does the sea-water which it is used to dilute.

Bearing these facts in mind, Professor Goldfarb repeated his experiments upon the relative rate of regeneration in *Cassiopea* in normal and in diluted sea-water, making use of distilled water in which the free CO_2 had been reduced by bubbling air through it which had passed through a soda-lime tube, and in which the residual acidity was neutralized by sodium hydroxide.

Professor Goldfarb also studied the efficiency of the sperm of individual echinoderms in fertilizing the eggs of individual females and found wide ranges in the ratio of fertilized to unfertilized eggs, dependent upon the individuals experimented with. By aging the extruded sex-cells Professor Goldfarb showed that fresh sperm-cells could fertilize the aged eggs, giving a decreasing number of fertilizations as the eggs became older, the decrease being about the same for all females; and conversely, a fresh egg could reactivate the aged sperm. The many interesting details of these experiments will be found in his report on pages 202 and 206.

Dr. Shiro Tashiro showed that in *Cassiopea*, if the marginal sense-organs be intact, the animal gives out more CO_2 than if they be removed,

even though the medusa may then pulsate at fully twice its normal rate by means of an entrapped stimulus. This is interesting in connection with Dr. L. R. Cary's discovery that if the sense-organs be intact the initial stages of regeneration are more rapid than if they be removed, and even a single sense-organ is competent to maintain this adjustment. There thus appears to be a profound control exercised by the central nervous system over metabolism and regeneration.

Other details of Dr. Cary's studies will appear in his preliminary report herewith presented, but it would be well to mention that he finds the alcyonaria to be an even more important factor in forming reef limestone than he had previously supposed.

Professors Alexander H. Phillips and Gilbert van Ingen made an extensive collection of marine invertebrates, which they dried and prepared, to enable them to determine what heavy metals, such as iron, copper, etc., these animals may contain. They also collected samples of the sulphureted mud from the mangrove swamps for a similar purpose. It is believed that certain deposits of iron and copper owe their origin to marine mollusca, worms, etc., and the subject should therefore be studied with existing animals. Several months must elapse before these investigators can present a report of their results.

Dr. Paul Bartsch again visited his plantations of cerions from Andros Island, which have been placed upon various Florida keys from the neighborhood of Miami to the Tortugas. He finds that the Florida-born young differ from their Bahama-born parents. The meaning of this can not be ascertained until several generations of Florida-born young have been produced, and until some of these have been returned to their ancestral locality on Andros Island and there observed. An intensive study of the habits, anatomy, possible differential death-rate, and embryology of these snails must also be made before conclusions can be established.

Professor Eugene W. Gudger continued his study of the anatomy of sharks, spending about two weeks at Key West before going to Tortugas for this purpose.

Professor Edwin E. Reinke continued his study of the physiological reactions of the two kinds of sperm-cells in *Strombus*, testing for the effects of CO_2 in sea-water under various conditions. These cells are exceedingly sensitive and somewhat variable in their responses, thus rendering this research so difficult that only an investigator of the highest determination, patience, and ingenuity could hope for success in its prosecution.

A. G. Mayer continued his studies of the rate of nerve conduction in *Cassiopea* in diluted and in concentrated sea-water, using for dilution distilled water freed from CO_2 and rendered slightly alkaline by N/10000 NaOH. Mayer's theory of nerve conduction is that sodium, calcium, and potassium cations of the sea-water are attracted by adsorption to the surfaces of negatively-charged colloidal elements of the nerves,

and the velocity of nerve conduction is proportional to the degree of concentration of these adsorbed cations, but this rate is accelerated by any free OH or H ions which may be present in the sea-water.

In another study, Mayer found that reef corals can still capture food until cooled within about 3° to 5° C. of their death temperature. Thus, if the ocean were cooled to 61° F., all the reef species would probably die from starvation if from no other cause, and it may be of interest to observe that the surface-waters of Florida are at times cooled to 63° F. by the northers of the winter months, and a heavy death-rate among the fishes occurs.

Dr. T. Wayland Vaughan, accompanied by Dr. E. W. Shaw, of the United States Geological Survey, spent two weeks upon the Tortugas, and, aided by Mr. Mills, they secured specimens of Texas Rock and other submerged ledges in the Northwest Channel. They also made shore-line maps of the Tortugas Keys and studied the submarine physiography of the lagoon, with a view to establishing the geologic history of the region. It may be said that Dr. Shaw confirmed the conclusions previously drawn by Vaughan respecting physiography and sedimentation and published in the Year Book for 1914. After completing this study, these gentlemen visited several of the Florida Keys between Key West and Miami, making use of the *Anton Dohrn* and her launches, the *Velella* and the *Henderson*.

Dr. Vaughan has now completed his study of the Tortugas region and, when published, the results of his investigation of the geologic processes, and of the coral reefs, their growth-rate, ecology, and geological status will be of great interest, demonstrating, as it does, the minor rôle corals have had as builders of limestones, and the importance of bacterial, chemical, and constructional agencies. It is to be hoped, therefore, that this most careful and intensive study of a coral-reef region which has as yet been made by any man of science may result in a volume accessible to all and creditable alike to Dr. Vaughan and to the Carnegie Institution of Washington, whose high privilege it was to afford him opportunities for these studies. He presents herewith a condensed report upon the rate of growth of corals which is the most complete and reliable account of the subject yet published.

George Matthai, B. A., Esq., of Emmanuel College, Cambridge University, made a collection of corals at the Tortugas and preserved the planulæ in various stages for histological and anatomical study.

John C. Waller, B. A., Esq., recently of King's College, Cambridge University, studied the electrical conductivity and potential in the leaf-stalks of plants, and presents a report herewith.

An interesting botanical investigation has been commenced by H. H. M. Bowman, of the University of Pennsylvania, upon the physiology, ecology, and growth-rate of the mangroves of southern Florida.

In addition to those who studied either at Porto Rico or the Tortugas, three investigators were aided in conducting researches in other regions, their work being either an extension of studies commenced at Tortugas or closely associated with the work of the Laboratory.

Of these, Professor Ulric Dahlgren continued his study of the histology of electrical tissue in fishes.

Dr. E. Newton Harvey visited Cuba to obtain and to endeavor to analyze the luminous substance which he has succeeded in isolating by solution from the bodies of both marine and terrestrial animals. In this connection he should be enabled to visit Japan in order to study the phosphorescent squid.

Dr. E. I. Werber received a grant to enable him to procure certain necessary things in connection with his research upon the control of the abnormal development of fish embryos.

Altogether the year has been one of varied and successful research, most of the studies opening the door to wide fields of scientific inquiry and thus assuring other even more progressive years to come in the endeavor of the Laboratory to advance the cause of experimental biology in the tropics. We have also determined the availability of various sites in the West Indies for scientific researches which in the future we hope to undertake, and while our plans must necessarily be conservative, due to the uncertainties of these troubled days of war, yet our prospect for continued usefulness never seemed brighter than at present, when, with the support of the ablest young students of our land and with the fruits of ten years of experience to guide us, the Laboratory has graduated from the experimental stage wherein many predicted its failure and has become one of our fixed and respected institutions of learning. Its national influence may be measured by the fact that of the 67 titles of papers upon biological subjects presented by students from all parts of the United States at the last meeting of the Society of American Zoologists in Philadelphia, 9 were upon work conducted under the auspices of the Department of Marine Biology. It is hoped that in coming years its part may become more prominent, and that the Laboratory may come to be not only a station known to Americans, but one of international service to science.

Volumes 7 and 8 of "Papers from the Department of Marine Biology" were published during the year by the Carnegie Institution of Washington, as publications Nos. 211 and 212.

Volume 7 contains the final report of Professor John B. Watson and his assistant, Dr. K. S. Lashley, upon the reactions of the gulls of Bird Key, and other birds, special attention being devoted to the cause of the "homing instinct," which, indeed, the authors do not explain, although they determine that sight and the sense of smell are not adequate to account for the homing instinct, and suggest that a "mag-

netic sense" may possibly be involved in the reaction. The homing instinct in the untrained noddy and sooty terns of Bird Key they find to be far superior to that even of the best-trained homing pigeon, these birds having made returns to Bird Key from Cape Hatteras, Havana, Mobile, and the middle of the Gulf of Mexico.

Experiments upon these birds led Watson and Lashley to investigate the law of habit-formation in man, and they find that practice for short intervals of time with well-timed intervals for rest is a more efficient method for learning than long-continued periods of practice with but little rest. Thus, in our schools, better results would be achieved by shorter mental strains alternating with periods of manual training, bodily exercise, or freedom from study.

Volume 8 of the Papers from the Department of Marine Biology contains 9 papers, the authors being Frank A. Potts (3 papers), Hubert Lyman Clark, Grace Medes, E. Newton Harvey, Alfred G. Mayer, Paul Bartsch, and Ulric Dahlgren; 7 of these result in whole or in part from studies conducted at the Murray Islands, Torres Straits, in 1913, while 2 others represent work done at Tortugas or elsewhere under the auspices of the Carnegie Institution of Washington. As most of these papers have already been reported upon in detail elsewhere, it will not be necessary to refer to them again, but it should be stated that systematic work upon the corals and the ecology of the reefs and upon the echinoderms of the Murray Islands remain to be published in quarto form, the authors being Drs. Vaughan, Mayer, Cary, and Clark.

The following papers are known to have been published elsewhere as a result of studies carried out at Tortugas or under the auspices of the Department of Marine Biology:

L. R. Cary: The Alcyonaria as a factor in reef limestone formation. Proceedings National Academy of Sciences, vol. 1, pp. 285–289, 1915.

E. W. Gudger: The Whale Shark, New York Zoologica, vol. I, pp. 349–389.—The gland of the clasper in sharks, and utero-gestation in the sharp-nosed shark, *Scoliodon terranovæ*. Science, vol. 41, pp. 435–439, 1915.

E. Newton Harvey: Cell permeability for acids. Internationale Zeitschrift für phys.-chem Biologie, Bd. I, pp. 463–478, Nov. 1914.

Alfred G. Mayer: Ecology of the Murray Island coral reef. Proceedings National Academy of Sciences, vol. 1, pp. 211–214, 1915.

——— The nature of nerve conduction in *Cassiopea*. *Ibid.*, pp. 270–274, 1915.

——— History of Tahiti, Fiji, Papua, etc. Popular Science Monthly, 1915.

T. Wayland Vaughan: Coral reefs and reef corals of the southeastern United States, their geologic history and significance. Bulletin Geological Society of America, vol. 26, pp. 58–60; Science, vol. 41, pp. 508–509, 1915.

This year the yellow-metal sheathing of the yacht *Anton Dohrn* was renewed and a funnel was constructed to serve as a ventilator for the engine-room; also a new engine was placed in the *Henderson*, thus rendering this launch as speedy as the *Velella*. Mr. John Mills, who had immediate charge of these installations and improvements, performed the work in a very commendable manner, and it is a pleasure to express the Department's appreciation not only of his services but those of

Captain George W. Tracy, William M. L. Wilson, and other members of the crew who served under them.

As in former years, so during this season, we have become still further indebted to Captain Edward Everett Hayden, U. S. N., commandant at Key West, for many acts of personal and official kindness.

It is also a privilege to acknowledge an indebtedness to our Secretary of State, who, moved by the request of President Woodward, kindly granted to the Director a letter of introduction to American consuls in the West Indies, which proved to be of decided advantage in this year of war.

REPORTS ON INVESTIGATIONS FOR THE SEASON OF 1914-1915.

Examination of Marine Organisms to determine their Capacities for Storing or Accumulating Metals, by Gilbert van Ingen and A. H. Phillips, Princeton University.

The senior author described at the meeting of the Geological Society of America in Philadelphia, 1914, the common occurrence, in noteworthy though not commercially valuable quantities, of the minerals sphalerite, galenite, chalcopyrite and other metallic sulphides and sulphates, in reef formations of early Paleozoic age, and announced his conviction that the organisms which formed the reefs had been responsible for the initial separation from the sea-water of the elements represented by these minerals.

The elements in question are zinc, lead, copper, nickel, barium, strontium, sulphur, fluorine. Iron and manganese were not considered in the same category, although it was recognized that these had in many cases been accumulated in vast quantities by organic agencies, as recently announced by Hayes, Dale, and van Ingen.

The organisms that made the ancient reefs were both animals and plants; *e. g.*, hydrocorallines, corals, alcyonaria, bryozoa, inarticulate brachiopods, and calcareous algæ.

The geological evidence is strong that these ancient organisms gathered the metals, known to be held in solution in the sea-water of to-day, and stored them in considerable amounts in their tissues or excreted them, and were thus responsible for the primary segregation of these metals in the sediments by which the organisms were entombed.

Search of the literature for information on the metal-storing activities of recent organisms yielded very little of value, but the work of Mendel and Bradley on the copper and zinc in marine mollusks was of such significance as to lead us to begin a research with the object of determining in some degree the extent to which marine organisms of the present day are engaged in storing up various metals in their tissues or causing the accumulation of metals by excreting them with their waste products.

The facilities of the Tortugas Laboratory of the Carnegie Institution enabled us to collect material, representing various groups of animals and algæ, which has been brought to Princeton for analysis. It was found impracticable to attempt any analytical work at the Tortugas Laboratory, for all of our time was occupied in gathering the material and preparing it by drying for shipment. This was done with due guarding against contamination from outside sources. It is our plan to supplement the Tortugas material by other collected from the north Atlantic coast and from fresh-water streams of this vicinity.

No results of analyses can as yet be given, but it is believed that a thorough examination of this practically untested field can not fail to yield results that may hold the highest interest not only in the domain of physiological chemistry, but also in their bearing upon the question of the organic origin of some of the great ore deposits of the world.

Report on Bahama Cerions planted on the Florida Keys, by Paul Bartsch.

The colonies near Miami were visited on June 18, 1915, but on account of the great number of mosquitoes on the keys it was impossible to make a proper examination and it was found necessary to return to Miami. On June 19 we returned to the keys and examined the colonies carefully. It was found that of the 50 tips of the first generation of Florida-grown "White House type" cerions planted on the outside of the north end of Sands Key last year, only a single specimen, about half-grown, was to be found. It is probable that most of the planted specimens survived and were not far away from the planting, but buried in the sand, for it was found in later visits that in places from which every visible specimen had been gathered, on the following day more mollusks were found clinging to the bushes in plain sight. The explanation was that the adult shells were probably buried in the coarse sand of the beach and that the scratching about and disturbing of this caused them to come to the surface during the night. On the first Ragged Key north of Sands Key we collected 46 of the originally planted "White House type" cerions and 23 adult specimens of the first generation of Florida-grown individuals, together with 45 young, varying in size from a quarter-grown to almost adult. The 23 specimens were carefully measured and photographed and replanted on June 21, about 50 feet north of the original planting, on the same sand ridge and in line with the landing stage. On June 21, when the original planting was again examined, 47 additional specimens were found under and upon several clumps of bushes which I had looked over quite carefully on the 19th; 16 of these were marked individuals from the original planting and 13 were adults of the first generation of Florida-grown specimens. These we marked by cutting scratches into the ribs with a knife and then planted them with the 23 in the new location. The 18 half-grown individuals we left with the original planting.

On the second key north of Sands Key, 76 adults of the first generation of Florida-grown individuals of the "King's Road type" were found, which were carefully measured, photographed, marked, and planted on the same key, about 70 feet south of the original planting, on the same sand ridge on which the original planting was made. We marked the place by cutting off the tops of the small bushes growing near the place of the planting.

Owing to the very poor conditions of the colonies last year on Tea Table Key and Indian Key, we did not stop to examine these this year.

On June 23 we visited the colonies on Bahia Honda. Here we found 56 full-grown individuals of the first Florida-grown generation and 23 ranging from quarter-grown to almost full-grown, but none of the originally planted specimens seem to have survived a fire which had visited this place. Most of the specimens found were in a ditch that appears to have escaped the fire. The adults were photographed, and all but one, which was reserved for further study, were marked and planted on the seaward side of the ditch, about 50 feet east of the coconut palm. We marked the place with a blue stake.

On the same day we visited Duck Key, where we found 46 of the originally planted specimens and 7 Florida-grown individuals of the first generation, a little less than half-grown. We left all of these in the old planting. This key has become so heavily overgrown with tall grass, *Sporobolus grandis*, that the cerions may not survive, since the grass appears to produce conditions much

more shady and probably more moist near the ground than those which exist in their original habitat along King's Road on Andros Island, Bahamas.

The colony at Newfound Harbor Key was not examined on account of its poor condition last year.

On June 25 we stopped at Boca Grande Key, where we found 119 of the first generation of Florida-grown specimens of the "Kings Road type." These we took to the Tortugas for photographing and measurement; all but 4 were returned to Boca Grande, where 103 adult and 9 young, duly marked, were planted about 300 feet south of the beacon, a little nearer the bushes than the shore, in a straight line inland from the *Tournefortia* bush which stands on the edge of the shore. The 4 specimens were reserved for the collection at Washington.

The colonies on the Tortugas were subjected to an examination between June 27 and 30. Here numerous adult specimens of the first generation of Florida-grown mollusks were found, but so far no adult specimens of the second Florida generation have appeared.

The status of these colonies may be summarized as follows:

Colony A.—The original planting of "White House type" cerions has spread considerably and is doing well. Adults and young of various sizes were seen everywhere within a radius of 50 feet from the stake marking the spot where they were placed in 1912; they have taken to the fringe of bay-cedars and have even crossed the path and are in the bushes to the west of it, but prefer the grass in the shade of the shrubs. Of the 162 marked specimens which we returned to the stake last year, 56 were found dead at the base of the stake; 16 marked, living specimens of the original planting, and 271 adults and 47 young Florida-grown individuals, the latter ranging from a quarter-grown to almost adult, were easily collected; these we placed near the stakes marking the original planting-place. The young individuals may represent first or second generation of Florida-grown cerions, and for this reason we shall pay no more attention to them, but shall permit them to mingle and develop undisturbed. A young individual of 9.5 whorls is a giant, measuring 14.2 mm. in diameter.

Colony B.—Here 500 tips of Florida-grown "White House type" cerions, offsprings of colony A, were planted last year. We recovered 125 full-grown or almost full-grown, and 14 immature specimens. These were measured, marked, and replanted as colony J, in a little clearing on the east side of the path halfway between the laboratory and colony A. We marked the place with a stake bearing the legend "Cerions 1915 J."

Colony C.—Here we planted 100 marked specimens, offsprings of colony A, in 1914, ranging from one-quarter to three-quarters grown. Of these, now adult, we recovered 36 this year, which were carefully photographed and measured, then returned to the same place, since there is no danger of a commingling between first and second generation individuals, as no second-generation specimens have as yet appeared.

Colony D.—On June 9, 1914, at my request, 200 specimens of mottled cerions, imported from Spring Hill, 6 miles southeast of Nassau, New Providence, were planted about 75 feet from the southeast corner of the main laboratory building on Loggerhead Key. We were this year unable to find a single specimen in the place where these shells were planted, and it is quite possible that they have been carried off by small hermit crabs, although some of them may be buried in the sand. We shall look for them again next year.

Colony E.—This is the original "King's Road type" cerion planting at the south end of the island, and is doing remarkably well, spreading rapidly northward in the little meadow. We found some of the specimens 115 feet from the

stake marking the place where they were liberated in 1912. Many of these snails have taken to the bay-cedars, which border the little meadow. We picked up 646 specimens, which may be of the first or of the first and second generations of Florida-grown specimens. We measured 250 of these and photographed the lot, then planted all of them in a little meadow to the west of the original planting, which is separated from this by a fringe of bay-cedars. We placed them in the north end of this meadow and marked the planting by a stake bearing the legend "Cerions 1915 K."

Colony F.—This colony consists of the 500 of the "King's Road type" cerions imported and planted in 1914 by Dr. Mayer. It is doing well. The adults were up on the grass and bushes. No young were seen; if any were present they were probably still very small and buried in the sand.

Colony G.—Last year we planted 300 specimens, ranging from mere tips to three-quarters-grown of the first generation of Florida-grown "King's Road type" cerions taken from colony E. Of these we recovered 49 adult or almost adult specimens, which were measured, photographed, and planted in the meadow a little to the west of colony K. We marked the place with a stake bearing the legend "Cerions 1915 L."

Colony H.—We planted a mixture of 500 each of the "King's Road type" and the "White House type" cerions in 1912. This colony we decided to transplant last year to a more favorable location, the old place having been partly burned over and partly swamped by a rank growth of cactus and grass. We cleaned up the place last year, by pulling up the cactus and hunting the ground over thoroughly; 200 of the "White House type" and 150 of the "King's Road type" were found and transferred to a new place, colony I. This year quite a number of specimens were found in the bay-cedars bordering the west side of the original planting which we must have overlooked last year. These we left there undisturbed.

Colony I.—Colony I was supposed to be all that was left in 1914 of the mixed colony H, which we transplanted to this new site. These specimens are doing well, but no young were noticed.

A new colony of a new strain of cerions, collected by Dr. Mayer at Ballena Point, near Guanica Bay, Porto Rico, was planted in a little meadow on the west side of the south end of the island. This colony consists of 800 specimens, which were marked as usual. The place of planting was marked by a stake, bearing a copper tag, with the legend "Porto Rico 1915."

The small colony on Bird Key has completely disappeared and no sign of cerions was found at the two plantings on Garden Key.

An Attempt to Colonize the Tree Snail, Liguus fasciatus, at Tortugas, by Paul Bartsch.

On our visit to Brickles Hammock, near Miami, Florida, this year, we found that the ground was being extensively cleared, which of course will mean the extermination of the splendid *Liguus* colony which occupies this hammock. It seems a pity that this magnificent mollusk, the largest and most beautiful of all the land shells native in our country, should thus be forced from this accessible locality. With the hope of colonizing it on the Tortugas, where the genus does not occur at present, 307 of the 319 specimens gleaned in an hour's walk through the hammock were transferred to these islands. These we divided into three groups:

First: Light-colored, without the mottled markings on the early whorls, of which there were 113.

Second: The dark-colored individuals without the mottled markings on the early whorls, of which there were 92.

Third: Those which have the early whorls mottled, of which there were 101.

The first (113) we planted in the trees in the angle between the main road and the first path to the left, within the fort, on Garden Key. The second (92) we planted on various kinds of trees and shrubs about the Laboratory on Loggerhead Key. The last (101) we planted in the small grove of cordia trees, on the east side and a little north of the lighthouse, on Loggerhead Key. The 12 remaining were left in the care of Miss Ruth Hayden, at the Naval Station at Key West, who placed them in the trees surrounding the commandant's residence. It is to be hoped that all these colonies will flourish and also that they may yield some data of interest to the biologist.

Birds Observed on the Florida Keys and along the Railroad of the Mainland from Key Largo to Miami, June 17 to July 1, 1915, by Paul Bartsch.

During the past two years lists of the birds observed in southern Florida and on the off-lying keys, while making my visits to the cerion plantations, were published in the Year Book of the Carnegie Institution. These observations were continued this year with the results noted below. This year's trip was a very hurried one which left little time for search. The specimens noted were seen without any special effort having been made to locate them. The birds observed this year are undoubtedly the breeding birds of the region, since the spring migration was long past and the autumn migration had as yet not set in. The observations made in 1913 extended from April 25 to May 9, while those reported upon in 1914 were made from April 20 to April 30.

The number of forms noted during the past two years was 76, to which 13 are now added, bringing the total to 89. The record published in 1914 of the occurrence of the white-eyed vireo (*Vireo griseus griseus*) on Sands Key, should, I believe, be changed to the Key West vireo (*Vireo griseus maynardi*) the prevalent form on the Keys.

June 17.—On a trip from Miami to the outskirts of the city taken this afternoon, the following birds were observed: Gray kingbird, Florida blue jay, mocking-bird, blue grosbeak, Florida cardinal, red-bellied woodpecker, ground dove, turkey buzzard, and Florida cormorant.

June 18.—A trip through lower Biscayne Bay showed several least terns, a brown pelican, a man-of-war bird, and a number of royal terns, the latter occupying the stakes marking the channel.

June 20.—A walk near the Royal Palm Hotel at Miami showed the presence of the red-bellied woodpecker, turkey buzzards, one black vulture, and a bald eagle.

June 21.—On a visit to Brickles Hammock, south of Miami, the following birds were noted: Mocking-bird, Florida cardinal, red-bellied woodpecker, ground dove, turkey buzzard, mourning dove, and Key West vireo.

On the afternoon of same day a call was made on the second Ragged Key north of Sands Key. Here we found the Florida cardinal and a green heron.

On the same day we also visited the first Ragged Key north of Sands Key, where the Florida cardinal and the Key West vireo were seen.

Sands Key was next examined and showed the presence of the Florida cardinal, the Key West vireo, and a man-of-war bird.

On our return through Biscayne Bay in the evening we found the Florida cormorant, brown pelican, man-of-war bird, and the royal terns, the latter, as usual, occupying the stakes marking the channel.

June 22.—Cape Florida: Quite a number of royal terns were seen on the channel stakes, but they are by no means as abundant as they were on the earlier date in the previous years.

Passing down Hawk Channel we observed one brown pelican and two man-of-war birds.

June 23.—On a visit to Bahia Honda Key we saw one gray kingbird, three ground doves, four least tern, one brown pelican, one royal tern, one laughing gull, and an osprey.

Duck Key on the same day yielded two pairs of gray kingbirds and one brown pelican.

June 24.—Key West: A trip in the morning along the main road from the town to the site of the new Bureau of Fisheries station, near Stock Island, showed several gray kingbirds and turkey buzzards and a man-of-war bird.

In the afternoon we visited Sands Key, where about 200 pairs of least terns were breeding, some having nests with fresh eggs, while in others these were in various stages of incubation. There were also many young birds present which ranged in size from newly hatched to almost completely feathered. In addition to these, two pairs of royal terns were seen.

June 25.—On Boca Grande Key we saw a man-of-war bird and a Ward's heron. In the afternoon of the same day we noted, on Loggerhead Key, man-of-war birds, sooty terns, and noddy terns flying over.

June 29.—A visit to Bird Key showed, in addition to the multitude of sooty and noddy terns, the presence of between 200 and 300 man-of-war birds, which were said by the keeper to be preying upon young terns. We actually saw one young tern picked up and carried to sea by one of these birds.

On the same day we visited Garden Key, where we noted some royal terns, a few least terns, and a couple of boobies occupying the stakes marking the channel.

We passed near Brush Key, where many least terns were flying about, and we were told that there were about 200 pairs of these birds breeding here.

June 30.—A very short stop at Boca Grande showed the presence of a man-of-war bird, some boat-tailed grackles, and a Ward's heron.

July 1.—On the morning of July 1 I left Key West on the train for Miami and taking a seat on the rear platform of our slow-going train I had a splendid opportunity to observe the birds along the stretch of keys joined by the railroad. I saw a number of species on this trip which I had not observed on the outer keys, and I therefore deem the following notes of interest.

Key West: Boat-tailed grackle, man-of-war bird, Florida crow.

Stock Island: Boat-tailed grackle, yellow-crowned night heron.

Boca Chica: Ground dove, red-winged blackbird, a flock of dowitchers, two American egrets, and an osprey.

Big Coppit Key: Boat-tailed grackle, osprey, two American egrets, and a yellow-crowned night heron.

Key between Big Coppit and Chase Key: Two American egrets.

Chase Key: One American egret, boat-tailed grackles, Bahama red-winged blackbirds, osprey, gray kingbird, mocking-bird, green heron, and turkey buzzard.

First key north of Chase Key: Ward's heron and green heron.

Sugar Loaf Key: Gray kingbird, mocking-bird, and Bahama red-winged blackbirds.

Cudjoe Key: Bahama red-winged blackbird, green heron, six least terns, and two royal terns.

On the muddy flats between Cudjoe Key and Summerland Key: Green heron, willet, and Bahama red-winged blackbirds.

Ramrod Key: Green heron and red-bellied woodpecker.

Torch Key: Bahama red-winged blackbirds, willet, and a couple of least terns.

Big Pine Key: Green heron, gray kingbird, mocking-bird, and black-whiskered vireo.

Spanish Harbor: Gray kingbird.

Bahia Honda: Osprey, gray kingbird, and Bahama red-winged blackbird.

Key between Bahia Honda and Duck Key: Osprey, Bahama red-winged blackbirds, Wilson's plover, green heron, boat-tailed grackle, and four brown pelicans.

Between Duck Key and the drawbridge a number of least terns were observed.

Pigeon Key: An osprey and a number of least terns.
Knight's Key: Brown pelican and an American egret.
Key Vaca: Florida cardinal, boat-tailed grackles, and green heron.
Crawl Key: American egret, green heron, and Bahama red-winged blackbird.
Grassy Key: Turkey buzzard.
Long Key: Florida cormorant, ground dove, and willet.
Jewfish Key: A few least terns and a laughing gull.
Lower Matecumbe Key: Green heron, boat-tailed grackle, and red-bellied woodpecker.
Upper Matecumbe Key: Laughing gull, royal tern, turkey buzzard, and ground dove.
Windly's Island: Brown pelican.
Long Island: Turkey buzzard and Florida red-shouldered hawk.
Tavernier Key: Bahama red-winged blackbird, gray kingbird, and mocking-bird.
Everglade Station: Ward's heron, Florida red-shouldered hawk, red-winged blackbird, and turkey buzzard.
Florida City Station: Gray kingbird, boat-tailed grackle, and Bahama red-winged blackbird.
Homestead Station: Loggerhead shrike, mocking-bird, and Florida bobwhite.
Perrine Station: Mocking-bird, Florida blue jay, Florida bobwhite, and downy woodpecker.
Keys Station: Mocking-bird, Florida bobwhite, and boat-tailed grackle.
Kendall Station: Turkey buzzard.
Larkin Station: Mocking-bird and downy woodpecker.
Cocoanut Grove: A pair of little sparrow hawks.
Miami: Florida blue jay.

SCIENTIFIC EQUIVALENTS FOR THE COMMON NAMES OF BIRDS USED IN THE PRECEDING LIST.

Laughing gull = Larus atricilla.
Royal tern = Sterna maxima.
Least tern = Sterna antillarum.
Sooty tern = Sterna fuscata.
Noddy tern = Anoüs stolidus.
Red-footed booby = Sula piscator.
Florida cormorant = Phalacrocorax auritus floridanus.
Brown pelican = Pelecanus occidentalis.
Man-of-war bird = Fregata aquila.
Ward's heron = Ardea herodias wardi.
Egret = Herodias egretta.
Green heron = Butorides virescens virescens.
Yellow-crowned night heron = Nyctanassa violacea.
Dowitcher = Macrorhamphus griseus griseus.
Willet = Catoptrophorus semipalmatus semipalmatus.
Wilson's plover = Ochthodromus wilsonius.
Florida bobwhite = Colinus virginianus floridanus.
Ground dove = Chæmepelia passerina terrestris.
Mourning dove = Zenaidura macroura carolinensis.
Turkey buzzard = Cathartes aura septentrionalis.
Black vulture = Catharista urubu.
Florida red-shouldered hawk = Buteo lineatus alleni.
Bald eagle = Haliaëtus leucocephalus leucocephalus.
Little sparrow hawk = Falco sparverius paulus.
Osprey = Pandion haliaëtus carolinensis.
Downy woodpecker = Dryobates pubescens pubescens.
Red-bellied woodpecker = Centurus carolinus.
Gray kingbird = Tyrannus dominicensis.
Florida blue jay = Cyanocitta cristata florincola.
Florida crow = Corvus brachyrhynchos pascuus.
Bahama red-winged blackbird = Agelaius phœniceus bryanti.
Boat-tailed grackle = Megaquiscalus major major.
Florida cardinal = Cardinalis cardinalis floridanus.
Blue grosbeak = Guiraca cærulea cærulea.
Loggerhead shrike = Lanius ludovicianus ludovicianus.
Black-whiskered vireo = Vireosylva calidris barbatula.
Key West vireo = Vireo griseus maynardi.
Mocking-bird = Mimus polyglottos polyglottos.

Report on Botanical Work at the Tortugas Laboratory for the Season of 1915, by H. H. M. Bowman.

The primary object of my going to the Tortugas Laboratory was to investigate the physiology, ecology, and other points in the life history of the red mangrove, *Rhizophora mangle*, and to some extent of the black mangrove, *Avicennia nitida.* A good beginning has been made, and during several weeks spent at Key West important data were secured on the rooting habits of both genera and the requirements and adaptability of the trees to various kinds of bottoms and solid media of growth. Some attempt was also made here to get a correlation between the distribution of the plants and the salinity of the water; this data has not as yet been worked out. Notes were also taken and water collected at a few of the upper Florida keys. The work on the distribution of the mangrove along the east coast of Florida has barely been glanced at during this season, but plenty of material was secured for morphological and histological studies to be pursued this winter.

At the Tortugas Laboratory a series of experiments was carried on with *Rhizophora* and some interesting curves were obtained for the transpiration of these plants under different conditions—*e. g.*, waters of various degrees of concentration and soils of different character. These experiments will be pursued with some variation in the methods of handling the plants next season, when it is hoped some practical difficulties can be overcome with the light of the experience gained this summer.

As secondary objects of study, mention may first be made of the curious spermatophyte which was brought up in dredging expeditions from water over 17 fathoms deep. The study of this plant promises to be interesting in its probable bearing on recent geological theories concerning the formations in this part of the Gulf of Mexico.

Another feature of this season's work was the botanical ecology of the Tortugas Group, which will be published as a special contribution. Lastly, a note may be given of a variation in *Conocarpus erecta* L., which was found at Fort Jefferson on Garden Key of the Tortugas a few days before the season closed.

Studies on Alcyonaria, by L. R. Cary.

Photographic records and measurements of gorgonian colonies cemented on tiles were continued during the present season. The results obtained confirm my previously published conclusions that the growth of all the common species of gorgonians, with one or two exceptions, is very slow after three years.

On the southern end of White Shoal, where, as stated in my report for last season, the bottom had been swept clean of all gorgonians by the hurricane of October 1910, the character of the gorgonian fauna has undergone a noticeable change within the last year. In July 1914 at least 95 per cent of all the gorgonians present were of the single species *Gorgonia acerosa*, practically all of which were of a size which indicated that they were about two years old. In July 1915 a considerable number of colonies of other species of gorgonians were found on the same reef area, together with many young colonies of *G. acerosa* which had become attached during the breeding-season of 1914. Over a large portion of this recently barren reef a luxuriant growth of gulf weed (*Sargassum bacciferum*) had become established, while in many small patches all sedentary animals have been destroyed by the algæ.

THE ALCYONARIA AS A FACTOR IN REEF LIMESTONE FORMATION.

The figures used as the basis for the estimates of the amount of calcium carbonate held as spicules in the tissues of the gorgonian colonies on any area of reef bottom in the region about Tortugas, which were published in the Year

Book of the Carnegie Institution of Washington for 1914, were obtained by determining the average weight of colonies of the several species taken from reefs in shallow water. When working upon the deeper reefs, where it was impracticable to remove the colonies from any given area, the number of colonies was ascertained and their average weight was assumed to be the same as that determined for the colonies from the shallow reefs.

The addition to the equipment of the laboratory this season of a "Dunn diving hood," by the use of which the study of any bottom in less than 30 feet of water is made practicable, has made it possible to obtain extensive collections of the alcyonarian fauna from the deeper reefs and to correct an error which had affected all of my estimates of the bulk of the gorgonian colonies growing on the deeper reefs. When seen from above, through depths of water greater than 15 feet, all except the very smallest gorgonian colonies appear to be of about the same size, and this average size does not appear to differ to any marked extent from that of colonies growing in shallow water. When the colonies growing on one of the deeper reefs were viewed from their own level, however, the aspect of that feature of the fauna was entirely changed. In many instances the surface of these reefs was covered with a dense shrub-like growth of gorgonians of an average height of at least 3 feet. Since the surfaces of all of the reefs are very irregular and the gorgonian colonies are commonly attached to the higher points on the reef, many of them would reach above the level of one's shoulders as he was walking about over the reefs. In general, the bulk of the colonies of the most common species of gorgonians was about twice as great as that determined for the same species from specimens collected on the shallow-water reefs. The average weight of the colonies of a number of these forms taken from a reef in 18 feet of water is given below:

Weight of gorgonian colonies from deep reefs.

Species.	Weight.	Species.	Weight.
	lbs.		*lbs.*
Eunecia rousseaui	2 20	Pseudoplexaura crassa	4 25
Eunecia crassa	0.75	Plexaurella dichotoma	2 00
Plexaura flexuosa	3.50	Gorgonia flabellum	3.00
Plexaura homomalla	3.00	Gorgonia acerosa	5.00

The proportion of spicules in the tissues of those forms for which spicule determinations were made of specimens from the deeper reefs did not differ materially from those determined for specimens from the shallow reefs, so that the estimate of 5.38 tons to the acre as the amount of spicules held in the tissues of living gorgonian colonies on the reefs about Tortugas would, for those reefs in more than 15 feet of water, be only about half of the amount actually present.

These observations tend to emphasize more strongly the importance of the alcyonaria as a contributing factor in reef limestone formation and necessitate a reexamination of the question of the life cycle of these forms, especially the relation of the depth at which they are attached to their growth-rate and length of life. As a preliminary attempt to secure this information, specimens of the same age of several species of gorgonians were cemented on tiles, some of which were fastened on the reef in 18 feet of water, while a corresponding set was planted in 3 feet of water in order to determine the difference, if any, in the rate of their growth under the two sets of conditions.

A number of forms of which small fragments only had been previously procured by dredging were found to be quite common constituents of the alcyonarian fauna on the deeper reefs.

Studies on the Physiology of the Nervous System of Cassiopea, by L. R. Cary.

THE INFLUENCE OF THE MARGINAL SENSE-ORGANS (RHOPALIA) ON THE RATE OF REGENERATION IN CASSIOPEA.

The results of my earlier studies on the relation of the sense-organs to the rate of regeneration in *Cassiopea* have shown that the one half of a medusa disk which is contracting normally under the influence of its sense-organs regenerates faster than the insulated other half of the same disk from which the sense-organs have been removed, so that it is inactive. Other experiments showed clearly that muscular activity is not the important determining factor of this difference in the rate of regeneration, but a sufficiently large number of observations had not been obtained to adequately determine the relative rates of regeneration under the different sets of experimental conditions.

The experiments this year were confined to those dealing with the effects of anesthetics; those in which disks were used on one half of which the sense-organs remained, while the other half was without sense-organs, but in the subumbrella tissue of which a continuous labyrinth was made by appropriate cuts and a circuit wave of contraction initiated by induction shocks. In the third type of operations all of the sense-organs were removed from the disk. A circuit wave of contraction was maintained in one half while the other was allowed to remain inactive. The data obtained from these experiments confirmed and supplemented those obtained from experiments performed in the same manner and reported in the Year Book of last year.

THE CONTROL BY THE SENSE-ORGANS OF THE RATE OF METABOLISM IN CASSIOPEA.

In the course of my series of regeneration experiments on *Cassiopea*, carried on during the season of 1914, Dr. S. Tashiro kindly made with the "biometer" a small number of determinations of the rate of metabolism, as expressed by CO_2 production, of the medusa disks under the different experimental conditions to which they were subjected in the regeneration experiments. As was to be expected, that half of any disk which was contracting normally under the influence of its sense-organs had a higher rate of metabolism than the other half of the same disk which had been rendered inactive through the removal of its sense-organs. When a half disk containing a circuit wave of contraction in its subumbrella tissue was compared with the inactive half of the same disk the rate of metabolism was found to be higher in the activated half. When, however, one compares the rates of metabolism of the two insulated halves of a disk, one of which retained its sense-organs (and was consequently contracting normally) while the other contained a circuit wave of contraction, it was found that the half upon which the sense-organs remained showed the higher rate of metabolism, although the half in which the circuit wave was entrapped was contracting at a much higher rate.

Since these few determinations indicated that the sense-organs exercise some control of the rate of metabolism of the medusæ that is independent of muscular activity, a more thorough study of this problem was undertaken during the present season, in collaboration with Dr. Tashiro. In all of our experiments the sense-organs were cut out from one half of the medusa disk with a small cork-borer, while from the other half an equal amount of tissue was cut from between the sense-organs. A continuous labyrinth of tissue was formed on the subumbrella side of the half disk without sense-organs and an entrapped contraction wave was set up by means of an induction current. A series of cuts of the same extent were made on the subumbrella of the half disk with its sense-organs, so that no error would be introduced on account of differences in the extent of laceration to which the different half disks had been

subjected. The separate half disks were put into jars containing 1,000 c.c. of sea-water and the amount of CO_2 given off by the disks during any given time was determined by means of a method perfected by Dr. Tashiro.

A record of the number of pulsations per minute was made for each of the disks. A count for each disk was made once each hour during the course of any experiment. While there were wide differences in the rate of both the half disks with sense-organs and especially in the rates of those in which a circuit wave of contraction was maintained, the latter half disks always contracted at a higher rate, which varied in different experiments from 1.10 to 6 times the rate of the corresponding half disk on which the sense-organs were retained. As the concentration of the CO_2 in the closed vessels increases the pulsation-rate at first rises slightly and then progressively declines until after a sufficiently long period of time the toxic effects of the gas would cause the complete quiescence of the disks. These effects of the increasing concentration of the CO_2 were much more quickly shown, and the decline in rate of pulsation was more rapid for the half disks with sense-organs than for the activated disks of any pair. The general average rate of pulsation for all of the experiments throughout their course was for the half disks with sense-organs 26.53 per minute, for the activated half disk 84.70 per minute; a proportion of 1 to 3.143.

In spite of this marked difference in the amount of muscular activity in any given period of time, the metabolism, as measured by CO_2 production, was with one exception actually greater from the half disk upon which the sense-organs remained than for the activated member of the same pair of disks, the two halves of what was originally an entire disk. In the single exception to this rule the activated half disk produced a slightly greater amount of CO_2 than the one with its sense-organs intact, but the difference was exceedingly small in proportion to the difference in the amount of muscular energy expended by the two half disks during the course of the experiment.

The Relation Between the Area of Tissue Enervated by a Single Sense-Organ and the Rate of Pulsation in Cassiopea.

Eimer[1] observed that there was a decrease in the rate of pulsation of a medusa disk the smaller the amount of tissue that was enervated by a single sense-organ. He stated that the rate of pulsation declined in direct proportion to the area of tissue controlled by the sense-organ. Romanes[2] pointed out that the decline in rate was not directly proportional to the area of tissue, but did not accurately determine the relation between area and rate. Mayer[3] confirmed Romanes's observation that the decline in rate is not directly proportional to the area enervated, but again did not determine the curve for the decrease in rate.

The records for 140 medusa disks, each with a single sense-organ remaining to control the pulsation-rate, showed that when the area under the control of the sense-organ was respectively the entire disk, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{16}$ of the original area, there is a fairly constant decline in the rate of pulsation from 35.55 for the entire disk to 16.75 when only one-sixteenth of the original area is under the control of the sense-organ. The complete record of the average number of pulsations for each area is given below, but no attempt at an analy-

[1] Eimer, Th., 1874, Ueber künstliche Theilbarkeit von *Aurelia aurita*, etc., Verhandl. physik.-Med. Gesellschaft Würzburg, N. F., Bd. 6.

[2] Romanes, G. J., 1895, Jelly-fish, star fish, and sea urchins, etc., International Scientific Series, vol. 49, New York.

[3] Mayer, A. G., 1906, Rhythmical pulsation in scyphomedusæ, Carnegie Inst. Wash. Pub. No. 47, 1906, pp. 9–10.

sis of the causes of this decline in the rate of pulsation with the decrease in muscular tissue involved was made at this time.

Area under control of single rhopalium.	Contractions per minute.	Percentage of original number of contractions.	Percentage of decrease.
One	35.55	100.00	00.00
One-half	30.45	85.77	14.23
One-fourth	25.70	72 39	27 61
One-eighth	22.58	63.60	36.40
One-sixteenth	16 75	47.12	52.88

Breeding Experiments with Porto Rican Lepidoptera, by John H. Gerould.

I studied the insect fauna of the island with a view to extending my experimental work in breeding polymorphic species. These investigations aim to throw light on the laws of heredity and the evolution of new species. Mr. Eugene G. Smyth, entomologist of the experiment station at Santa Rita, near Guanica, with the cooperation of Mr. F. T. Maxwell, general manager of the Guanica Central, generously offered the use of his insectary and assisted me in many ways.

Preliminary experiments were begun in mating and breeding pierid butterflies of the genera *Terias* and *Callidryas.* Two species of the former occur together in nearly equal abundance at Guanica (*T. euterpe* and *T. palmyra*), which afford excellent possibilities for experiments in hybridization. Their pronounced and distinctive color-patterns, small size, and easily controlled mating make them especially favorable for experimental breeding in large numbers.

After leaving Guanica and the south coast, I spent several days in the mountainous interior, first at Adjuntas, where I met and cooperated with Dr. F. E. Lutz and Mr. A. J. Mutschler, of the American Museum of Natural History, who were engaged particularly in collecting Hymenoptera and Coleoptera, and subsequently at Maricao. Still later I visited the experiment stations at Mayaguez and at Rio Piedras, where, through the kindness of the entomologists, Messrs. R. H. Van Zwalenburg of Mayaguez and G. N. Walcott of Rio Piedras, I examined the collections of Porto Rican insects.

An inviting object for investigation observed at Adjuntas and Maricao is *Leptalis spio,* the pierid "mimic" of *Heliconius charitonius.* The latter is abundant in the shade of coffee and banana trees covering the glens and hillsides. In the same regions, less abundantly, with similar habits of flight, occurs the "mimic." The specimens observed and collected were not, however, of the color of the heliconid "model," yellow and black, colors that are possessed in other parts of the island by the "mimic," but of orange and black. This orange and black variant of *Leptalis spio,* well known to entomologists, is possibly, and indeed probably, the result of a mutation that may have some time taken place in the stock of the yellow and black "mimic." If so, this would be an example of a mutation tending to destroy rather than create "mimicry." The genetics of the two varieties of this polymorphic so-called mimic present an inviting field for investigation. The genetic relationship of the two varieties to one another, their bionomic relation, if any, to *Heliconius charitonius* (the "model"), the life history of which should be studied simultaneously with that of *Leptalis spio,* are matters of unusual and manifold interest.

Experimental Studies upon Stale Germinal Products, by A. J. Goldfarb.

Ripe eggs and sperm when removed from the bodies of the sea-urchin *Toxopneustes variegatus* undergo changes the nature of which I sought to ascertain. To reduce the number of variables, all eggs and all sperm were made in standardized suspensions, all products from a given individual were kept separate, and the temperature, density, surface, and volume of the sea-water were constant.

A.

(1) In the first place, it was found that fresh suspensions of the sperm from different individuals varied remarkably in their power of fertilizing the eggs from a given female, though morphologically the different sperm suspensions were indistinguishable. The range of variability extended from 100 to 0 per cent of fertilization.

(2) A fresh suspension of tested sperm gave widely different results with different females, though their eggs were otherwise indistinguishable. They varied from 100 to 20 per cent of fertilizations.

(3) Low or high degree of fertilizability is specific for a given male or a given female.

(4) Only by experiment may we ascertain which eggs and which sperm will give optimum results.

B.

Tested eggs and sperm removed from the body and kept at the temperature of the laboratory, or slightly below this temperature, show definite changes with increasing time-intervals, namely, in the reaction-time of fertilization membrane formation, in the changes of the membrane itself, in the rate of cleavage, in the character of the cleavage, and in the structure of the larvæ. In the first place, the longevity of eggs from different individuals was ascertained and also the longevity of concentrated suspensions of sperm, as determined by the power of fertilizing or being fertilized. Freshly prepared and tested eggs when fertilized by freshly prepared and tested sperm served as controls. Stale eggs, *i. e.*, eggs after increasing intervals subsequent to their removal from the body, were fertilized by correspondingly stale sperm, until the limits of fertility were reached. In a third series of experiments increasingly stale eggs were fertilized by freshly prepared sperm suspensions, and lastly, fresh eggs were fertilized by increasingly stale sperm.

(1) It was found that increasingly stale eggs of a given female, though fertilized by freshly prepared sperm suspensions at each trial, gave a decreasing number of fertilizations, and that this decrease was approximately the same for all females.

(2) With increasing staleness of the egg, the rate of fertilization membrane formation is at first progressively decreased, then sharply increased. The time at which this sharp change occurs is significant.

(3) The fertilization membrane is increasingly gelatinized.

(4) The permeability of this membrane is markedly altered.

(5) The rate of cleavage is progressively retarded.

(6) The number that cleave irregularly is increased.

(7) The number of atypic larvæ is correspondingly increased.

When increasingly stale and tested sperm were used to fertilize freshly prepared and tested eggs, their development was quite normal. None of the changes just enumerated took place, showing that the deleterious factors symptomized by these changes are potent or present in the eggs exclusively. This is surprising in view of the apparent lower metabolism of the latter.

When increasingly stale and tested eggs were fertilized by increasingly stale sperm there was no additional change; the results are altogether like those obtained with stale eggs by fresh sperm.

A number of experiments were also made with a view to finding out the nature of the factors that gave rise to these changes, with particular emphasis upon the influence of the alkalis in sea-water and of the calcium content. These will be described in full elsewhere.

The CO_2 Factor in the Regeneration of Cassiopea xamachana, by A. J. Goldfarb.

The striking resemblance between the curve for the rate of nerve conduction in *Cassiopea* when CO_2 is present in the distilled water used to dilute the sea-water, and the curves obtained by the writer in the regeneration of the same organism when placed in different concentrations of sea-water suggested the possibility that the supernormal regeneration in diluted sea-water may not only be due to changes in salinity, but also to differences in the amount of CO_2 added with the distilled water. If this were found to be the case, the resemblance would have considerable significance.

To test this hypothesis, sea-water was diluted with the same water (rain-water) used in previous experiments. In a second series distilled water was used, from which nearly all the CO_2 had been removed. Inasmuch as there was still a trace of CO_2 in excess of sea-water in both these waters (the exact amount of which was determined), sufficient NaOH was added to neutralize the free acid in the solution. In another series more NaOH was added, not only to neutralize all the free acid, but some of the acid (CO_2) given off by the pulsating organisms during the next 24 hours. A comparison of these series of experiments should have established the influences of the graded amounts of CO_2 in the different concentrations of sea-water upon the regenerating animals with their total of 640 regenerated arms.

While each series of experiments differed in certain details from the other series, yet there was no significant difference. All showed the same rise in the curve between 100 per cent and 80 per cent sea-water, as in the experiments of 1914.

The experiments made known many complicating factors not heretofore suspected, which factors need further study. So that it seems inadvisable at the present stage of the inquiry to make any definite conclusions.

The Fishes of Southern Florida, by E. W. Gudger.

SHARKS.

During the two and a half weeks spent at Key West, with a gasoline launch at my command, I had expected to have no trouble in getting sharks as heretofore, *i. e.*, by going around to the city abattoir, selecting the shark, harpooning it, and towing it to my working-quarters for description, measurement, and dissection. However, it was found that almost nothing in the form of bait was being thrown overboard at the slaughter-house, and that no sharks had been seen for weeks. In fact, but one shark was gotten there, and that was caught by some boys and kept for me. In this dilemma, I resorted to hook-fishing, with the services of the best fisherman in Key West. Here but indifferent success was had; two fish a day were caught when any were taken, but there were many barren days. However, six large sharks were caught, and were carefully described, measured, and dissected. Nearly all were females, but unfortunately none were breeding. However, careful notes were made of the structures of the reproductive organs, with a view to eventually working

up a paper on the method of reproduction in the sharks of this region. The indications are that all the sharks taken were viviparous. Three of these were *Galeocerdo tigrinus*, one being a marked melanistic variation. There is now at hand sufficient data for a careful description of this shark, that heretofore given being very imperfect. The other sharks all belonged to the genus *Carcharhinus*, one being a species apparently not recorded heretofore from Florida, and another a species not yet identified.

At Tortugas I got only three sharks in my two weeks' stay. One of these was an unknown *Carcharhinus*, and the other a shark which we were unable to classify by the use of Jordan and Evermann's Fishes of North and Middle America. It is hoped that it may be a new species. Photographs, descriptions, and measurements were made of all these doubtful specimens, and teeth and pieces of skin were preserved for help in classification. Photographs were also made of the reproductive apparatus and eggs of a nurse shark, *Ginglymostoma cirratum*. These will be used to illustrate a forthcoming paper on this shark.

TELEOSTS.

My time being almost entirely spent in fishing for sharks, not much attention was given to the bony fishes. However, notes were made as heretofore on all new or interesting forms which came in. With a view to a study of its natural history, especial attention was paid to the *Echeneis* or *Remora*. A number of very small specimens have been collected at Key West, and under the care of a capable fisherman these are being added to, and it is hoped that this will be the best collection of small specimens of *Echeneis* to be found anywhere. It is known that the young fish differs considerably in the structure of its tail from the adult, and it is hoped that this collection will enable one to determine the character of the change.

Preliminary Report on the Chemistry of Light Production by Luminous Animals, by E. Newton Harvey.

On June 26 the writer sailed for Havana, Cuba, to collect the Cuban cucullo, a luminous elaterid beetle, *Pyrophorus havaniensis*, reported abundant during the summer in the cane regions near Havana. Headquarters were established at the Agricultural Experiment Station at Santiago de las Vegas and trips were made into the surrounding country to Guanajay and Güines, and a five days' excursion to the mountains in Pinar del Rio near Bacanagua. Unfortunately, the height of the season (during May and June, depending on the rains) for the beetles was past and not enough material could be obtained for the carrying out of the chemical work intended. Preliminary studies were undertaken and arrangements made for the shipping of beetles north to Princeton during the height of the season next spring, when research will be continued. I am deeply indebted to Dr. J. F. Crawley, Director of the Experiment Station, and Mr. C. N. Ageton, of the chemical department, for their kindness during my stay at Santiago de las Vegas.

The proposed study of the West Indian cucullo is merely a continuation of research on the chemistry of biophotogenesis in the common fire-fly and in luminous bacteria on which the writer has been engaged for the past two years. Most favorable results have been obtained and an extensive investigation of other luminous forms is planned. It can be stated definitely now that the luminous substance is easily capable of solution and isolation, provided an abundant supply of luminous material can be obtained. A phosphorescent squid (such as that of Japan, or certain molluscs) seems most favorable, and it is hoped that an opportunity of studying these forms will present itself in the near future.

Coloration of Tropical Reef Fishes, by W. H. Longley.

Between the middle of May and the first of August, my investigation of the colors of tropical reef fishes was continued in Porto Rico and Tortugas. Distinct progress was made in the attempt to determine what law, if any, may be apparent in the character and distribution of the pigments externally visible in this group of animals. Present and prospective advance is associated with the recognition of three facts:

First, in these fishes the dependence of the various color-phases upon the character of the environment may be demonstrated most clearly by observation of individuals over a series of simple bottoms, covered, for example, by bare white sand, brown algæ, or the green blades of turtle grass (*Thalassia testudinum*); for over mixed bottoms, where many colors may appear in small patches, animals which seem to be exposed to the same conditions have been recently or are being acted upon by different stimuli whose separate effects it is very difficult to dissociate.

Second, those species which may be observed at a given station may be arranged according to habit in subclasses in which, upon the whole, there is much narrower range of color than in the larger group.

Third, conspicuousness is largely dependent upon the relative position of the observer and the observed object.

Dr. Charles H. Townsend, Director of the New York Aquarium, has described the color-phases of a number of Bermudian fishes confined in aquaria in New York, and is inclined to correlate them with specific psychic states, such as anger or fright, or specific activities, such as playing or feeding. Some of these fishes, together with others whose color-phases are undescribed, have been under my observation in their natural habitat, where their reactions lend slight support to Dr. Townsend's hypothesis. But I find that in some species I am able to evoke different color-phases at will by tempting the fishes to swim from one locality to another of different and definite character whose influence one may forecast with precision.

As a result of such experiments or of observations many times repeated upon fishes whose movements were uncontrolled, I am able to state that color change is commonly induced by change in the environment and is dominated by the color character of the environment which actuates it. This conclusion applies to the following species: *Iridio bivittatus* and *I. maculipinna*, *Lachnolaimus maximus*, *Monocanthus hispidus* (young), *Sparisoma abildgaardi*, and *S. flavescens*, *Sphyræna barracuda*, and the young of *Thalassoma bifasciatus*, which are described as *T. nitidus* and *T. nitidissima*. Since some of these display those bright hues or have patterns involving those strong contrasts in color whose occurrence has led to the introduction into biological theory of the hypotheses of warning and immunity color, we must believe that fishes are common in which conspicuousness is concomitant with obliterative counter-shading and adaptive color change, or accept the conclusion that the alleged conspicuousness of these colors and patterns is overrated through some misconception of the mode in which they cooperate with counter-shading and color change to secure the maximum degree of inconspicuousness in a very difficult situation. Happily, in the choice of alternatives, one is not left to weigh these probabilities, for the trend of the evidence is decidedly in favor of the second.

The coincidence of a given color with a specific habit, *e. g.*, the practical restriction of red among shallow-water fishes to those which lie concealed by day and feed at night, is in itself sufficient to raise the gravest doubts regarding the truth of those hypotheses which postulate conspicuousness. For it is remarkable that out of more than 100 species which I have observed, 5 bearing this color, usually rated as conspicuous, fall in a single subclass defined by

agreement in habit, while among the others (which include many accepted as examples of warning or immunity color) red is almost unknown even as a minor element in a color scheme.

The facts regarding red are in harmony with a general rule which is gradually becoming apparent, that coincidence in habit is correlated with agreement in pigmentation. Of 18 species (5 red ones included) which do not range over the open reef freely by day, not one has a conspicuous gray phase, nor is one marked with the sandy gray color of barren bottoms. Conversely, of 29 species which do range over the reef comparatively freely by day, 17 have a gray phase or permanent gray markings constituting an important element of their pattern, and 10 show definitely, though in varying degrees, a color adjustment converging toward that of the gray bottom, when they swim over or come to rest upon it.

Additional evidence that there has been misconception regarding the function of color appears from a consideration of certain fishes which are marked with blue-gray or blue. *Abudefduf saxatilis* is such a one, commonly considered conspicuous by observers viewing it from above. However, when it is seen from a lower level its contour is visible at times not more than 15 feet from the observer, for its blue-gray markings are resolved into the blue-gray haze which at that depth surrounds one on all sides and in lateral view nothing is seen but several parallel bars of brown and yellow. The chub (*Kyphosus sectatrix*) and the runner (*Caranx ruber*) may be almost invisible to an observer at the same or a lower level than they are themselves. The limitations imposed by time prevented the pursuit of this portion of the investigation to its logical conclusion, but the suggestion that shades of blue may be assigned a definite significance is one of the most interesting that appears at present.

With regard to aspects of the general problem as yet of subordinate interest, it may be stated that facts bearing upon the phylogeny of the color patterns of the fishes continue to accumulate and that the inadequacy of the color descriptions of the tropical fishes becomes more apparent as familiarity with their color changes increases. As an example of confusion resulting from incomplete knowledge of color change, it is to be noted that *Bodianus fulvus* and *B. punctatus* are two color phases of one species of which one may almost instantaneously replace the other.

Preliminary Report on the Comparative Morphology of the Recent Madreporaria around Tortugas, by George Matthai.

During the short stay I made at Tortugas (July 17 to August 1) my work was limited to general observations on the coral fauna and coral reefs of that locality. With the facilities at the Laboratory, it was possible to make an extensive collection of all the common species for subsequent examination of their soft and hard parts. I hope to commence the investigation of this material after my return to Cambridge, England, at the end of 1915, and finally, to incorporate the results with my studies on the Comparative Morphology of the Madreporaria, which were begun at Cambridge University in 1911, mainly on collections made by Professor J. Stanley Gardiner, during his expeditions to the Indo-Pacific ocean. Such a comparative study will, it is hoped, give us a better understanding of the anatomy and relationships of the corals of the Indo-Pacific and Atlantic regions.

All the common forms of coral were kept under observation in the Laboratory. The only species that extruded larvæ was *Favia fragum;* none of these, however, settled during the course of the fortnight I remained at Tortugas.

The Chemistry of Nerve Conduction in Cassiopea, by Alfred G. Mayer.

In 1914 it was found that if we place ring-shaped strips of subumbrella tissue of the scyphomedusa *Cassiopea* in sea-water, diluted either with distilled water or with 0.415 molecular magnesium chloride, the rate of nerve conduction declines in accordance with the formula $y=2\,x^{0.86}$, where x is the concentration of the cations sodium, potassium, and calcium in the diluted sea-water, that in normal sea-water being 100; and y is the relative rate of nerve conduction in the same diluted sea-water, that in normal sea-water being 100. This formula resembles the well-known one for chemical adsorption, and suggests that negatively charged colloidal elements of the nerve may attract the sodium, potassium, and calcium cations to their surfaces, and that these adsorbed cations conduct the nerve impulse.

The exponent 0.86 is higher than in the usual adsorption formulæ, this being due to the H ion of H_2CO_3 present in the distilled water used in diluting the sea-water; the H ion in weak concentration is well known to be a powerful stimulant, while in greater excess it is a depressant.

This season (1915) these experiments were repeated, the sea-water being diluted, however, with distilled water which was so far as possible freed from carbon dioxide by having bubbled through it air which had passed through a soda-lime tube, after which the water was rendered slightly alkaline by adding 1/10000 molecular NaOH. This showed that in common with the H ion, the OH ion is also a stimulant for the rate of nerve conduction in weak concentration, and a depressant in stronger concentration. It is necessary, therefore, to make use of neutral distilled water in order to determine the true effects of the sodium, calcium, and potassium cations. In the purest distilled water obtained in 1915, which, however, contained some free OH ions, the formula for the rate of nerve conduction was $y=2.512x^{0.8}$.

It seems possible, therefore, that the nerve stimulus may be conducted by adsorbed cations of sodium, calcium, and potassium, but this rate of nerve conduction is accelerated by any OH or H ions which may be present.

W. M. Bayliss, 1915 (Principles of General Physiology, p. 61), states that heat dissociates an adsorption compound. This, together with the onset of asphyxiation at high temperatures, may account for the fact shown by Harvey, that the rate of nerve conduction in *Cassiopea* rises more slowly with rise in temperature than one would expect were it a simple chemical reaction; the OH ions tending to follow the van't Hoff exponential equation for chemical activity with rise in temperature, while the adsorbed Na, Ca, and K, being reduced in concentration, tend to lower the rate, which is still further lowered above 33° C. by the development of heat asphyxiation. These suggestions are presented merely as a *possible* explanation of the phenomenon of nerve conduction.

The Solution of Limestone in Sea-Water, by Alfred G. Mayer.

Thin pieces cut from a compact shell of the mollusk *Cassis*, having a specific gravity of 2.88 and ranging in superficial area from 57.6 to 85 sq. cm., were used in these experiments. Two glass carboys were sterilized by washing them successively with HCl, KOH, alcohol, and distilled water, and one of these was filled with 45 liters of sea-water which had been doubly filtered and then heated within the carboy to 72.5° C., thus sterilizing it. The other carboy was filled with the same volume of sea-water taken directly from the ocean and neither filtered nor sterilized. Also, two 15-liter glass vessels were inclosed in black, light-tight wooden boxes, so as to form dark chambers to prevent plants from growing within them, and were so arranged that if placed

between tide-levels the vessels would be filled and emptied through small glass tubes by each rise and fall of the tide without creating strong currents within the vessel. One of these vessels was placed at the end of the wharf on the western side of Loggerhead Key, where pure ocean-water might enter it. The other vessel was placed in the moat at Fort Jefferson. When examined one year later, it was found that in the vessel off the Loggerhead Key wharf a tunicate *Ciona* had grown within the vessel, so as to stop the entrance and thus to prevent the circulation of water. The bottom of this vessel was covered with about 8 mm. of limestone mud which had been drawn in through the glass tubes, and which gave off an odor of sulphureted hydrogen, but the water within the vessel was inhabited by a number of marine animals, such as two forms of *Ciona*, an *Alpheus*, and several worms and mollusks, all of which were alive and seemed normal in appearance, and some of which had grown to be too large to escape from the vessel through the glass tubes. The contained shell was buried beneath the mud.

The circulation in the vessel placed in the moat at Fort Jefferson was properly maintained and there was almost no mud in the bottom, so that the shell remained surrounded by sea-water throughout the year. Carefully weighed pieces of the *Cassis* shell were placed in each of these four vessels in July 1914 and removed in July 1915. The air temperature throughout the year ranged from 15° to 37° C., the average being about 27°. The experiment shows that

Rate of solution of pieces of Cassis shell in sea-water.

Conditions of the experiment.	Weight in July 1914.	Loss in weight after one year's immersion in sea-water.	Years required to dissolve entire shell.	Thickness of limestone removed from the surface of the shell in one year.
	gm.	*gm.*		*mm.*
Shell placed for 367 days in 45 liters of doubly filtered sea-water sterilized by being heated to 72.5° C. At the end of the year this sea-water still retained 71 per cent of its alkalinity by phenolphthalein test....................	*13 285	0 014	948	0.00067
Placed for 360 days in 45 liters of sea-water dipped from the ocean in a glass vessel. At the end of the year this sea-water was acid, and contained green algæ and bacteria. Its free acidity (over and above neutrality) was equivalent to N/3000 H_2SO_4, tested by phenolphthalein	15 532	.173	90	.007
Placed for 364 days in the moat at Fort Jefferson in a 15-liter dark-chamber bottle, the water being changed by each rise and fall of the tide. This bottle maintained its circulation throughout the year. The moat water contains more CO_2 and is less alkaline than that of the open sea, but remains alkaline to phenolphthalein test...	10.5435	.0115	917	.00069
Placed for 364 days in a 15-liter dark-chamber bottle surrounded by pure sea-water. The shell was found buried under 8 mm. of mud in the bottom of the vessel. The circulation of the water had been interrupted and the mud was charged with H_2S.	15.22	.047	324	.0019

*The balance was accurate to 0.001 gm.

limestone dissolves in sea-water which remains alkaline during the process of solution, but that this solution is slow. This supports the conclusion of Dr. Shiro Tashiro, that normal alkaline sea-water contains some substance, probably free CO_2, which dissolves limestone. The amount of this free acid is, however, so slight that its effect as a solvent is practically negligible, and Vaughan is correct in his contention that the sea-water *as such* has not been a significant factor in deepening the lagoons of atolls through solution.

For example, the thickness of calcium carbonate removed from the surfaces of these shells ranged from 0.00067 to 0.00069 mm. after a year's immersion in *alkaline* sea-water, and the shell which was buried beneath the mud and subjected to H_2S as well as to CO_2 lost a superficial thickness of 0.0019 mm. in a year. Taking this latter figure as a maximum rate of solution of limestone *due to sea-water as such*, it appears that the time required to dissolve out a depth of 20 fathoms would be 19,250,000 years, or about 1,000,000 years to a fathom, and as many lagoons 15 to 20 fathoms deep appear to have been formed since the beginning of the Recent period, it is evident they have not been caused by solution due to sea-water as such, for even if reef limestone dissolves 100 times as fast as did this *Cassis* shell it would require 144,000 to 192,500 years to form the present lagoons.

The chief factors causing solution of submarine limestone in coral-reef regions are undoubtedly fresh water draining off the forested shore, holothurians, echini, fishes, boring algæ, and sponges, and numerous other animals and plants, which swallow or dissolve limestone, but even all these taken together are not sufficient to prevent the silting up of most atoll lagoons, as has been well shown by Guppy, F. Wood-Jones, Vaughan, and others.

The Lower Temperature at which Reef Corals Lose their Ability to Capture Food, by Alfred G. Mayer.

Upon gradually cooling the sea-water within which hungry reef corals are living, it was found that they gradually lost their activity, and with it their ability to capture food (crab or snail meat). Food *already captured*, however, could be held upon the surface of the tentacles or other parts to within 1° of death temperature, whereas the corals lost the power to seize fresh pieces of crab meat at about 3° to 5° C. above death temperature. Thus:

Name of coral.	Temperature at which food can no longer be captured.
	°C.
Siderastrea radians.....	10.5 to 17.3
Porites furcata . ..	14 5 14.7
Acropora muricata ...	17.4 17.8
Mæandra areolata.. ...	16.3 18.6

Thus at about 61° F., or 16° C., most of the reef corals would be unable to capture food, and doubtless a sustained exposure to such a temperature would be fatal.

Report upon the Behavior of the Dimorphic Spermatozoa of Strombus, by Edwin E. Reinke.

As was reported in the Year Book for 1914, it was proposed to continue, during the season of 1915, at the Tortugas Laboratory, the experiments on the behavior of the spermatozoa of *Strombus*, using an artificial sea-water instead of natural sea-water. It had been found that there was a considerable amount of variation in the behavior of the spermatozoa in cultures made with pure

natural sea-water, even when all other factors were kept constant, and it was thought that the use of an artificial sea-water with which some preliminary tests had been made would obviate this difficulty. Accordingly, a large quantity of artificial sea-water was made up, following a formula based upon F. W. Clarke's analysis of the sea-water at Tortugas, *i. e.*, 100 c.c. of 0.6 m $NaCl$+17 c.c. of 0.4 m $MgCl_2$+3.5 c.c. of 0.4 m $CaCl_2$+2.1 c.c. of 0.62 m KCl.

In the report upon the experiments with this artificial sea-water last year, it was stated that the behavior of the spermatozoa of *Strombus* in this medium corresponds very closely with that in natural sea-water. This, however, is not exactly the case, as was shown this year by an exhaustive series of comparative tests. It was very clear that in artificial sea-water the spermatozoa do not become as quickly active nor do they reach as great a degree of activity as they do in natural sea-water. On this account it was found to be impossible to use the artificial sea-water as contemplated. When a culture is started under standard conditions in natural sea-water, the eupyrene spermatozoa reach a maximum degree of activity within 3 to 5 minutes and at the end of that time they are either largely or entirely loosened from the tufts in which they lie in the sperm-ducts. Eventually they all become freed and swarm about freely. When a culture is started in artificial sea-water, the eupyrene spermatozoa become active very much more slowly (10 to 15 minutes) and only about 50 per cent become loosened from the tufts. Unless practically all the spermatozoa are free and active, it is impossible to interpret accurately any mass reaction on their part to a bubble of gas introduced into the culture. It is interesting to note that no significant difference in the behavior of the apyrene spermatozoa in natural and in artificial sea-water was observed.

It is evident that there is something lacking in the artificial sea-water which is present in natural sea-water and which causes full activation of the spermatozoa. At present there is no known method whereby an artificial sea-water can be made up which will resemble natural sea-water in this respect. Furthermore, it has been found that, so far as the spermatozoa of *Strombus* are concerned, the addition of a small percentage of natural sea-water to a volume of the artificial solution will not rectify the latter. However, when sea-water was added in increasing proportions, it was found that the behavior of the spermatozoa became more and more as it is in pure natural sea-water. For this reason it was suspected that the element that is so essential for the full activation of the spermatozoa is not an enzyme, but rather the peculiar chemical balance, not fully understood, which is known to exist in natural sea-water.

A series of experiments was consequently undertaken in order to determine, if possible, whether there is an actual variability in the alkalinity and acidity of sea-water and, if there is, whether it corresponds to the variation which had been observed in the behavior of the spermatozoa in cultures made in pure sea-water under constant conditions. For this purpose samples of sea-water were titrated to phenolphthalein by a special method in which the procedure was always kept constant. The samples were varied as regards temperature, atmospheric conditions, and locality. After titration a culture was made from the sample and observations were made upon the time which it took the spermatozoa to become fully active and the degree of activity reached. The results of these experiments show that, under the conditions of the test, sea-water does vary. It was, however, impossible to perform a sufficient number of experiments to determine whether this variation is correlated with changes in temperature, tide, time of day, or locality. These variations are slight and it is questionable whether they could have any effect upon the behavior of the spermatozoa. Such data as was obtained from the comparative cultures would also indicate this, although hardly sufficient upon which to base a definite statement.

Fishes New to the Fauna of Porto Rico, by Charles F. Silvester.

Of the collections made in the vicinity of Guanica by the writer during the latter part of May and the early part of June 1915, the fishes, batrachians, and reptiles have proven to be most interesting. The batrachians, reptiles, and crustaceans are being worked up by Henry W. Fowler, of the Academy of Natural Sciences of Philadelphia, whose report will be published shortly.

More than 100 species of fishes were collected. Of this number about 20 per cent were new to the fauna of Porto Rico and 8 per cent were new to science. Following is a preliminary report of the fishes new to science as well as those not heretofore recorded from the island:

MURÆNESOCIDÆ.

MAYERINA gen. nov.

Body long, round, pencil-like, same caliber throughout, does not taper in tail region except rather abruptly near end. Teeth uniserial, canine-like, sharp, anterior enlarged; single series of sharp canine-like teeth on palatine. Fins very low, rudimentary, dorsal and anal beginning behind vent. Distinguished from *Stilbiscus* Jordan and Bollman in the continuous dorsal and anal fins; pectoral very small and rudimentary. One species known.

Type, *Mayerina mayeri* sp. nov.

Mayerina mayeri sp. nov.

Head 9.5 in body, 4.3 in tail. Depth same as upper jaw, about 65 in total length. Lower jaw projecting; anterior nostril tube-like, near end of snout; posterior nostril larger, in front of eye. Gill-opening one-half the isthmus, which is same length as snout. All fins very rudimentary, microscopic, excepting caudal; pectoral less than one-half width of gill-opening; dorsal and anal begin length of head behind vent and continue as very fine lines to end of tail, where they enlarge into the easily visible caudal. Lateral line present and prominent, with series of microscopic, open pores; blood-vessel follows course of and shows through skin on lateral line.

Color in life orange-yellow above; ventral surface slate-blue, merging into whitish in anterior part of tail region; posterior part of tail entirely yellow; iris blue. Tip of lower jaw and area behind eye reddish.

Two specimens of this beautiful little eel were obtained on the sand flats around mangrove swamp west of Guanica Harbor at very low tide.

Length, 31 cm.

Type, No. 3073, Zoological Museum, Princeton University. Paratype, No. 3126. Zoological Museum, Princeton University, 28 cm. long.

(Named for Dr. Alfred G. Mayer, director of the expedition.)

ECHELIDÆ.

Myrophis longleii sp. nov.

Head 3.5 in trunk, 5.5 in tail. Depth of body at gill-opening 3.3 in head. Upper jaw projecting; teeth sharp, more or less irregular on maxilla and vomer, indicating two series; series more or less single on mandible. Eye 2 in width of snout between anterior nostrils. Vertical fins well developed; dorsal beginning two-thirds length of head in front of vent, anal beginning directly behind vent; both continuous into caudal, which is wider and completely surrounds end of tail. Anterior nostril tube-like, near end of snout; large pore above this on top of snout. Posterior nostril, so called, below eye in upper lip.

Color in life, light olive-green with very fine punctation above, lighter below.

Length, 12 cm.

Type No. 3083, Zoological Museum, Princeton University.

Dug from sand flats west of Guanica Harbor.

(Named for Dr. W. H. Longley, in recognition of his investigations upon the color of fishes.)

OPHICHTHYIDÆ.

Myrichthys keckii sp. nov.

Head 4 in trunk, 9.5 in total length; eye 3 in snout, which is 2.6 in head. Teeth more or less blunt in single series; vomerine teeth present. Pectoral small, as wide as gill-opening,

but very short and rudimentary. Isthmus about 3 times width of gill-opening. Numerous pores on top of head and on lower jaw; large round pore on center of opercle. Anterior nostril near end of snout in large tube which projects downward. Posterior nostril under eye in lip. Dorsal well developed, begins on nape and extends to near tip of tail; anal very low, beginning directly behind vent and extending to near tip of tail. Tail very little projecting beyond dorsal and anal.

Color in life very light transparent green, darker above, series of about 20 darker spots along lateral line, hardly distinguishable in life.

Branchial chamber rather large.

One specimen, dug from mud flats near mangrove island west of Guanica Harbor.

Length, 7 cm.

Type, No. 3082, Zoological Museum, Princeton University.

(Named for my friend, Mr. Thomas Keck.)

SYNGNATHIDÆ.

Corythroichthys ensenadæ sp. nov.

Rings 18 + 33; dorsal 19 on 1 + 4 rings; pectoral 12; caudal 10; anal 2. Head 9. Eye 5. Body 1.5 in tail. Cranial ridges strong, median keel on snout to middle of eye; ridge on occiput high, notched behind. Supraocular ridge beginning in tubercle in front of center of eye; two ridges on opercle. Nostril double, in front of and near eye, tubed, dorsal tube short, ventral tube longer. Keels on body and tail strong; lateral keel of body running into ventral caudal keel Belly convex, keel strong.

Body with 22 yellow and 22 brown rings, which divide more or less on ventral surface of belly in rings and blotches of brown. Brown rings edged with darker. Rings on snout become irregular spots and blotches. First complete brown ring crosses interorbital space through eye and obliquely downward and backward to large brown area on ventral surface of opercle.

Length, 10.5 cm.

Type, No. 3084, Zoological Museum, Princeton University.

From bunch of coral off Ballenas Point.

(Named for a party of friends from Ensenada who obtained this specimen.)

BELONIDÆ.

Tylosurus notatus Poey.

One specimen 26 cm. long. Seined among mangrove islands west of Guanica Harbor.

No. 3121, Zoological Museum, Princeton University.

CHEILODIPTERIDÆ.

Apogonichthys stellatus (Cope).

Three specimens 1.5 to 2.5 cm. long. This fish lives in dead sea-urchin shells. Almost every sea-urchin skeleton in small muddy area west of Guanica Harbor was inhabited by one of these fishes.

No. 3048, Zoological Museum, Princeton University.

Amia conklini sp. nov.

Head 2.6; depth 2.7; eye 2.6; interorbital 3.2; D. VI–1, 9; A. II, 8–9; scales 2–27–7; eye large; head broad; mouth rather large. Lateral line complete, following curve of back to caudal peduncle, where it dips down to center line.

Color orange-red with clusters of small black specks over entire body. Caudal peduncle with large oblong black spot; caudal edged with black; spinous dorsal black; soft dorsal and anal with black bar on base; a black bar extending downward and backward on front of preopercle from eye; another bar extending transversely on nape and down on opercle, where it is more or less broken up into series of dots. Differs from *A. sellicauda* in color markings, larger eye, and more robust body.

Two specimens 4 and 5 cm. long obtained with dynamite on coral reef off Guanica Harbor.

Length, 5 cm.

Type No. 3080, Zoological Museum, Princeton University. Paratype No. 3128, Zoological Museum, Princeton University, 4 cm. long.

(Named for Professor E. G. Conklin.)

CENTROPOMIDÆ.

Centropomus pectinatus Poey.

One specimen, about 20 cm. long, from Guanica Lake.

SPARIDÆ.

Diplodus argenteus (Cuv. & Val.).

From coral reef off Guanica Harbor.

SCIÆNIDÆ.

Eques pulcher Steindachner.

One specimen, 5 cm. long, from cluster of coral rock in shallow water west of Guanica Harbor.

No. 3097, Zoological Museum, Princeton University.

POMACENTRIDÆ.

Microspathodon niveatus (Poey).

One specimen, about 5 cm. long, from coral reef off Guanica Harbor. Several specimens of this rare species were seen swimming among the coral rocks along the side of the cliff in the entrance to the harbor west of Guanica Harbor

Mycrospathodon fowleri sp. nov.

Head 3; depth 1.87; dorsal XII, 15; anal II, 13. Scales 3–29–10. Eye 4.25. Body compressed, but rounded, profile from snout to dorsal evenly rounded; slight indication of fleshy crest at nape in 1 individual, not indicated in 4 individuals. No fleshy corrugations on anterior profile in 4 individuals, indicated in 1 individual Nostril small. A pigmented, fleshy, tongue-like flap in roof of mouth. Upper teeth small, movable, in semicircular series, teeth of lower jaw large and fixed, in a series rounded in front and concave on sides. Caudal peduncle about 2.5 in head, depth 2.25 in head, dorsal elevated and ending in a pointed tip behind. Color uniform deep black to uniform bluish black, with indication of yellowish tinge under scales, fins uniform black.

Length, 19 cm.

Type, No. 3060, Zoological Museum, Princeton University.

Five individuals ranging from 13 to 19 cm. long. From coral reef off Guanica Harbor.

(Named for Henry W. Fowler, in recognition of his contributions to ichthyology.)

LABRIDÆ.

Harpe rufa (Linn.)

One specimen, about 15 cm. long, from coral reef off Guanica Harbor

MONACANTHIDÆ.

Pseudomonacanthus amphioxys (Cope).

Three specimens from coral reef off Ballenas Point.

GOBIIDÆ.

Sicydium antillarum (Ogilvie-Grant).

Several specimens from 5 to 12 cm. long obtained from mountain streams flowing into the Arecibo River in the vicinity of Utuado.

Gobiosoma multifasciatum (Steindachner).

Two specimens, 2 and 2.5 cm. long, found attached to coral rocks in shallow water east of Guanica Harbor.

GOBIESOCIDÆ.

Gobiesox cerasinus Cope.

Quite common around coral reefs in vicinity of Guanica Harbor. Usually hidden in crevices of rocks.

BLENNIIDÆ.

Rupiscartes macclurei sp. nov.

Head 4.2; depth 4.3; dorsal XI, 20, or XII, 19=41; anal 22. Head slightly longer than deep; anterior profile vertical, slightly convex. Pectorals reach to vent or beyond in male, not quite to vent in female. Upper lip of male large; teeth pectinate; canines large; fringe around upper and lower lips, upper pigmented, lower not pigmented. Supraocular tentacle slender; large tentacle medial to each anterior nostril, which divides into 5 or 6 tentacles; two nucal tentacles in male, smaller in female. Numerous large pores on head, one group behind and below eye, another on supraopercular region. Dorsal fin entire, extending from nape to caudal; last dorsal ray bound down for two-thirds of its length; last anal ray free.

Differs generally from *R. atlanticus* in coloration. Color brownish generally, livid purplish on costal region; filaments above eyes and edges of lips bright orange. Iris slaty. Dorsal olive-greenish, with median dusky lengthwise band anteriorly, contrasting strongly with whitish or pale upper half of fin, but sloping up behind so that edge of dorsal is dusky posteriorly. Upper front edge of dorsal broadly orange below, with submarginal area of whitish. Caudal olivaceous, dusky medianly, grayish below, yellowish above; anal dark neutral tint, edge blackish; pectoral pale orange, red on lower half; ventral pale.

Two specimens from dead coral reef west of Guanica Harbor.

Length, 5.5 cm.

Type, No. 3081, Zoological Museum, Princeton University. Paratype, No. 3027, Zoological Museum, Princeton University, 5 cm. long.

(Named for Professor C. F. W. McClure, for his researches upon the lymphatics of fishes.)

Further Studies on CO_2 in Sea Water and CO_2 Production in Tropical Marine Animals, by Shiro Tashiro.

The work done this year at the Marine Biological Laboratory at Tortugas between July 2 and August 2 is a continuation of the researches begun last summer. The original plan was to investigate the effects of temperature on the metabolism of tropical marine animals and their isolated tissues, but this was somewhat modified on account of the interest which has been aroused by the question of "free CO_2" in the sea-water, which, at the request of Dr. Mayer, I have again attempted to investigate.

Tube.	Indicator.[1]	Added.	Results.
A	25 c.c. PsP′.	75 c.c. sea-water.......	Faint pink.
B	25 c.c. PsP.	75 c.c. distilled water...	Decided pink.

[1]Phenolphthalein-sea water; prepared by heating sea-water to 85° C. with crystals of phenolphthalein, then adding an equal volume of sea-water and again heating to 90° C.

In spite of the presence of a certain amount of free CO_2 in the distilled water used, and enough free OH ions present in the sea-water to turn phenolphthalein pink, tube B is much pinker than tube A. The question arises whether this is due to effects of electrolytes on phenolphthalein, or the effects of electrolytes on the condition of free H and OH in sea-water. If there is free CO_2 in sea-water, the dissociation of H_2O in the sea-water must be entirely different from that found in pure water.

If we now add N/100 NaOH to tube A, until it matches the color of tube B, we must have neutralized free CO_2, if the original pale color of tube A was due to the presence of free CO_2 in the sea-water; but if one now adds 1 c.c. excess of N/100 NaOH to the distilled water in B, it requires 7 c.c. more N/100 NaOH to cause the color of A to equal the intensity of B. This ratio 1:7 is fairly constant until it suddenly breaks at the point where the NaOH causes a

precipitation of $CaCO_3$. This point varies according to the condition of the sea-water. For example:

A. 100 c.c. sea-water + 10 drops of phenolphthalein + 1 c.c. N/100 H_2SO_4 + 1 c.c. N/100 NaOH.
B. 100 c.c. sea-water + 10 drops phenolphthalein.

Tube A is pinker than tube B, thus showing that A contains less free acid than does B. A definite amount of N/100 NaOH must be added to B to cause its color to match that of tube A. This amount varies with the amount of N/100 H_2SO_4 added, but reaches a maximum at the point where enough N/100 H_2SO_4 has been added to neutralize the normal carbonate (titrated in the cold with phenolphthalein). The less alkaline the sea-water is at Tortugas, the more acidity it will lose after exactly equal amounts of N/100 H_2SO_4 are added, followed by N/100 NaOH.

A. 100 c.c. sea-water + 10 drops phenolphthalein + 2 c.c. N/100 H_2SO_4 + 2 c.c. N/100 NaOH .... Decided pink.
B. 100 c.c. sea-water + 10 drops phenolphthalein + 2 c.c. N/100 NaOH + 2 c.c. N/100 H_2SO_4 .... Faint pink.

The amount of N/100 NaOH which must be added to B to make its color match that of A is a function, as stated before, of the original amount of N/100 H_2SO_4 added, also of the amount of sea-water used. At Woods Hole, in a certain sample of sea-water, 2.5 c.c. N/100 H_2SO_4 will completely decolorize the pink color of 100 c.c. sea-water. The maximum loss of acidity in this sea-water was 0.3 c.c. of N/100 H_2SO_4 for 100 c.c. of sea-water. For example, if there is added in sequence (Woods Hole water):

(*a*) A 250 c.c. sea-water + 10 drops of phenolphthalein + 6 c.c. N/100 H_2SO_4 + 6 c.c. N/100 NaOH .... Decided pink.
B. 250 c.c. sea-water + 10 drops of phenolphthalein + 6 c.c. N/100 NaOH + 6 c.c. N/100 H_2SO_4 .... Faint pink.

It was necessary to add 7 to 8 c.c. of N/100 NaOH to B to cause it to assume the same intensity of color as that of A.

(*b*) A. 100 c.c. sea-water + 10 drops of phenolphthalein + 6 c.c. N/100 H_2SO_4 + 6 c.c. N/100 NaOH .... Decided pink.
B. 100 c.c. sea-water + 10 drops of phenolphthalein + 6 c.c. N/100 NaOH + 6 c.c. N/100 H_2SO_4 .... Faint pink.

To B we had to add 0.3 c.c. of N/100 NaOH to cause it to become as dark in color as A.

These experiments show there is in sea-water a certain amount of some form of CO_2 which becomes lost when an acid is added, and this amount is a function of the amount of sea-water used, and not of the amount of acid added. Thus, in these experiments the maximum loss of acidity is represented by 2.5 c.c. of N/100 H_2SO_4 for each 100 c.c. of sea-water. This amount is from 6.6×10^{-7} gram to 9×10^{-7} gram of CO_2 per c.c. of sea-water, which is a little above that contained in air at the present time.

I can not assert that this CO_2 contained in sea-water is "free," but the following experiments are extremely suggestive:

(*a*) Sea-water at Tortugas loses CO_2 continuously.

(*b*) If one precipitate $CaCO_3$ from sea-water by adding an excess of NaOH so that the $CaCO_3$ coats the sides of the bottle, and if one then wash the bottle several times with sea-water carefully and shake constantly, thus freeing all NaOH from the bottle, but leaving a certain amount of precipitated $CaCO_3$ adherent to the sides of the bottle, and then fill the bottle with fresh sea-water; if one compare this sea-water with natural sea-water after both have been standing 24 hours, it is found that the sea-water in the bottle which contains the precipitated $CaCO_3$ is less acid than natural sea-water. Also, the loss of acidity corresponds nearly to 6.6 to 9×10^{-7} grams of CO_2 per cubic centimeter of sea-water or about to that stated above.

Thus natural sea-water dissolves $CaCO_3$ and appears to lose a certain amount of CO_2 in the process, but we hesitate to assert that this action is due to *free* CO_2 in the sea-water.

If there is free CO_2 in sea-water, dissociation of H_2O in the sea-water must be quite different from that of pure water.

The theoretical considerations, together with quantitative data, for which this report affords no space, will be published later.

Further Studies on CO_2 Production in the Medusa Cassiopea.

A new and rapid method was devised to estimate amounts of CO_2 produced in sea-water by marine animals. I extended the previous study of small circular pieces of the animal to the half or the whole animal. Very extended quantitative data were collected on the metabolism under the following conditions:

1. Effect of contraction (resting and contracting).
2. Effect of light on both resting and contracting medusa.
3. Size and metabolism.
4. Under different concentrations of sea-water (*electrolytes*).
5. Effect of temperature (not complete).
6. Effect of sense-organs (with Dr. Cary).

The general conclusions are exactly the same as those of last year, but the averages for the production of CO_2 under these different conditions have yet to be calculated, and until this has been done we can not present a report.

Report on Systematic Study of the Leodicidæ in 1915, by A. L. Treadwell.

My work in 1915 was a continuation of that of previous years on a systematic study of the Leodicidæ. In Porto Rico, no representatives of this family were found in Guanica Harbor, but *Leodice fucata* (the palolo) and *Nicidion kinbergii* occur in the coral rock off the entrance to the harbor, and *L. rubra* is abundant in the channel at its entrance. These are all common forms at the Tortugas. A *Leodice* and a *Marphysa*, both probably new species, were collected in coral rock near Guanica Lighthouse.

In Condado Bay, near San Juan, I collected a few *Marphysa fragilis*, which was previously known only from a very limited locality at Loggerhead Key in the Tortugas; and a small *Lysidice* was found in the hard rock on the seaward side of the shore of the bay. Other annelids, especially capitellids, *Clymenella*, and *Chætopterus*, are numerous in Condado Bay, but no attempt was made to collect them.

In Florida, collections were made in Key West Harbor, at Boca Grande and Marquesas Keys, and at the Tortugas. In the former localities, species of *Marphysa* and of lumbrinereids were most abundant, while at the Tortugas, *Leodice* is the most common genus. In my report for 1914, I said there are no mud flats in this locality; this proves to have been erroneous, as mud flats have formed at Long Key since the great hurricane of October 1910, and *Onuphis* and lumbrinereids occur there. Some species not previously seen in the Tortugas were dredged at various places in the channels and off the south shore of Loggerhead Key. These are mostly very small forms, living in crevices in the loose, broken coral rock. About 90 drawings have been made of the species collected this year, and it is probable that practically all of the shallow-water Leodicidæ occurring in the Tortugas have now been described and figured.

According to previous records, the swarming of palolo should have occurred this year between June 30 and July 6, for the moon's last quarter fell on July 3.

I was absent from the Tortugas during the greater part of this time, and did not observe the swarming. To my friend Dr. Longley I am indebted for the information that on July 1 he saw large numbers of worms lying on the bottom among the coral reefs. While these specimens were not actually identified, the fact that specimens of palolo collected after July 5 had lost their sexual ends makes it evident that the worms he saw were really palolo, and that the swarming occurred on July 1.

On Recent Madreporaria of Florida, the Bahamas, and the West Indies, and on Collections from Murray Island, Australia, by Thomas Wayland Vaughan.

Dr. Mayer forwarded to the U. S. National Museum, for study and report by me, a set of Recent corals and a set of bottom samples and rocks from Murray Island, Australia. As soon as other duties permitted, reports on these collections were undertaken by myself and my collaborators. The manuscript on the Recent corals, now nearing completion, includes an account of the collection Dr. F. Wood-Jones made in the Cocos-Keeling Islands, which he has generously donated to the U. S. National Museum, and contains descriptions and figures of about 120 species of corals from the two areas. The bottom samples were divided and a portion of each sent to Dr. F. K. Cameron, of the U. S. Bureau of Soils, who has communicated the results of physical analyses. Dr. Albert Mann, of the U. S. Bureau of Plant Industry, has reported on the diatoms, and Dr. Joseph A. Cushman, of the U. S. Geological Survey, has furnished a preliminary report on the foraminifera, which will be supplemented by the descriptions of some technically new species. Dr. Marshall A. Howe, of the New York Botanical Garden, is preparing an account of the coralline algæ, which will soon be complete, and Mr. E. W. Shaw, of the U. S. Geological Survey, is describing in detail the bottom deposits and the rock specimens.

A brief remark on the Murray Island bottom samples is appropriate here. Unless it be in the relatively small percentage of material less than 2 μ in diameter, there is no bacterially precipitated calcium carbonate in the samples, but specimens of Coccolithophoridæ ranging from 14 to 20 μ in diameter are abundant, and occasionally one has a diameter of 30 μ. These belong to the group of forms known as *Pontosphæra*. Besides these, there are disks 2 to 5 μ in diameter, which are probably coccoliths. In the presence of these small calcareous organisms and in the absence of conspicuous amounts of bacterially precipitated calcium carbonate, the Murray Island reef is similar to the barrier reef off Andros Island, Bahamas. One of the common organisms on the Murray Island reef is the foraminifer *Tinoporus bacculatus*, which at the station on line I, 1,600 feet from shore, forms about 70 per cent of the material.

In accordance with Dr. Mayer's suggestion that he would defray the expenses of an expedition to St. Thomas, Danish West Indies, if the U. S. National Museum would detail a collector, Mr. Clarence R. Shoemaker was assigned to the work. He left New York for St. Thomas on June 19, and returned to Washington on August 2, 1915. Unfortunately, high winds prevailed all the time he was on the island, making work on the outer reefs impossible. However, he obtained about 21 species of shoal-water corals, and made considerable collections of the other organisms associated with them. He also made a collection of Recent land mollusca, which are being studied by Dr. Bartsch for the light they may throw on the extent and age of former land connection between the islands, previous to the submergence which has affected all the Virgin Islands. In addition to this material, Dr. Mayer has sent to the U. S. National Museum collections of corals from Barbados and Porto Rico. All of these collections are being utilized in studying the Recent West Indian coral fauna.

The collecting of daily water samples at Fowey Rock, off Miami, Florida, throughout one year is now nearly finished. Mr. R. B. Dole, of the U. S. Geological Survey, has titrated the samples for salinity as they were received and has made twelve composite samples, one for each month, composed of an equal amount of water from each daily sample. He is quantitatively determining the amount of calcium in each composite, and will make a complete quantitative analysis of a composite composed of all the monthly composites.

Last year Dr. Mayer put on the rocks, under the landing for the laboratory pump wharf, the corals used in the light-exclusion experiment. Seven of the specimens were recovered,[1] and the following records were made on July 21, 1915:

Orbicella annularis: 1 specimen, part of which is pale, with no zoanthoxellæ, but in other places the colony has resumed its normal color.

Orbicella cavernosa: 2 specimens, both alive, somewhat damaged apparently by rolling; still a little paler than usual.

Mœandra clivosa: 2 specimens, (1) color gray, otherwise normal; (2) pale, but part of the specimen is brown.

Siderastrea radians: 2 specimens, (1) most of it of normal, brownish color; (2) has some light patches.

Siderastrea siderea: 2 specimens, of normal, brownish color, have grown appreciably.

These specimens not only survived being in the dark for 43 days, but before the end of a year were again very nearly or quite normal. The fact that the corals are not normal in the dark, although they will endure the exclusion of light for a considerable period, and the fact that corals are absent on the central piers under Fort Jefferson wharf, where it is dark, while they are abundant on the peripheral piers, is strong evidence in favor of light being one of the ecologic factors determining the locus of species of corals.

Three additions were made during the season to the list of the Tortugas coral fauna, as follows:

Madracis decactis (Lyman) and *Agaricia nobilis* Verrill were dredged at a depth of 18 fathoms south of Tortugas Buoy. *Phyllangia americana* M.-Ed. & H. and *Stephanocœnia intersepta* (Esper) were dredged in 16 fathoms (these are not new records for the Tortugas, but it was interesting to find the species). A fine specimen of *Mycetophyllia lamarckana* M.-Ed. & H. was collected by Mr. George Matthai on the piers of Fort Jefferson wharf.

Growth-rate of the Floridian and Bahaman Shoal-Water Corals.

Except to allude to the continuation of the experiments and observations, no specific report on the results of the study of the growth-rate of corals has been published since the one in Year Book No. 10, pp. 148–156, plates 4–6, where all data then available on the size of year-old corals were presented. The technique for rearing and planting corals and that for measuring corals growing under natural conditions are described in Year Book No. 10 and in Year Book No. 9, pp. 136–144, plate 1. The descriptions there given need not be repeated here. It was stated in the last Year Book, p. 225, that the investigations of growth-rate, except the remeasurement of colonies reared from planulæ or of known age, were terminated. The colonies on which additional records were desired were remeasured in July 1915, and they also have now been taken up and shipped to Washington.

During the past winter I had all records on growth-rate copied on appropriate schedules, and since my return from Tortugas I have added the records made during July of this year and have had the average annual rate for the

[1]For records made in 1914, see Year Book 13, p. 223.

specimens representing each species at each station computed. A tabular statement of the annual averages is presented on a subsequent page.

As the object of the investigation should be made clear, it should here be stated that stony corals are not suitable subjects for a critical study of the laws of growth-rate. The proportion of living tissue to the stony skeleton is relatively small, and as the skeleton after very young stages usually is not entirely covered by the living soft parts, other organisms may attach themselves to the previously formed skeleton and increase its weight, or boring organisms may enter the skeleton, begin its destruction, and decrease its weight. As many boring organisms have calcareous tests, they destroy a part of the original skeleton and add the weight of their own. Minute algæ, as Duerden has shown, bore into the skeleton and ramify through it almost or quite to the boundary of the living soft parts. Weights obtained from specimens cemented to disks are subject to all the sources of inaccuracy enumerated, and also to the impossibility of restoring the disk to its initial condition after affixing and planting a specimen, because of organisms attaching themselves to its surface. These remarks render it clear that the object of the investigation is not to make a contribution to the laws governing growth-rate. However, it will later be made evident that some of the principles of growth-rate of some species have been ascertained. The actual object of the investigation has been to aid in understanding the relative amount of work stony corals may do as constructional geologic agents, and especially in the formation of those calcium-carbonate structures designated "coral reefs."

In order properly to evaluate corals as constructional agents, the subject needs to be studied from at least five different view-points, viz: (1) In dealing with sediments uplifted above the sea, the quantity of material contributed by corals and that contributed by other agents must be estimated and the respective proportions determined; (2) in coral reef areas, the proportion of the area covered by corals to that not covered by them should be estimated; (3) the relations of coral reefs to continuity and discontinuity of marginal submarine platforms must be ascertained; (4) marine bottom deposits must be analyzed according to the source of the material, and the percentage of the calcium carbonate contributed by the different agents estimated; (5) the rate of growth of corals needs to be known, especially for the light it may throw on the rate of reef formation.

That corals have been tremendously overevaluated is established. In this connection, I introduce Murray and Renard's table giving the composi-

Average composition of the "Challenger" samples of coral mud and of coral sand.[1]

Composition.	Coral mud.		Coral sand.	
Carbonate of lime:				
Pelagic foraminifera	31.27		36.25	
Bottom-living foraminifera	14.64		20.00	
Other organisms	39.62		30.59	
		85.53		86.84
Residue:				
Siliceous organisms	1.36		5.00	
Minerals	1.00		3.75	
Fine washings	12.11		4.41	
		14.47		13.16
		100.00		100.00

[1]"Challenger" Repts., Deep-Sea Deposits, p. 246, 1891.

tion of their "coral sand" and "coral mud" and some analyses Quin has made of the calcareous sand on the shores of St. Croix Island, Danish West Indies.

Analyses of sea-sand from Cane Bay, St. Croix Island.[1]

Origin.	Number of grains. No. 1.	No. 2.	No. 3.	Total	
Vegetable:					
Fragments of Nullipore (mostly red)	14	34	27	75	155
Fragments of Calc. Weed (Halimeda)	7	24	13	44	
Fragments of Corallines	3	23	10	36	
Animal:					
Foraminiferous shells (whole and fragments)	19	47	34	100	158
Shells, molluscous (mostly fragmentary)	6	21	15	42	
Fragments of Echinus spines	3	2	4	9	
Fragments of small crustaceous shells	1	0	1	2	
Minute Serpula tubes	0	3	1	4	
Fragments of Echinus shell	0	1	0	1	
Agglutinated grains (same substances)	1	6	9		16
Not determined	8	14	11		33
Totals	62	175	125		362

[1]Quin, John T., The Building of an Island, p. 15, 1907.

These statements show that Murray and Renard should not have applied the terms "coral sand" and "coral mud" to the material so designated by them; while Quin did not fall into their error.

From the tables on pages 227 and 228 it will be seen that there is no single formula for the growth-rate of corals, as the rate of growth is different for different species and in each species it varies in accord with differences in local ecologic conditions. In order to understand the factors controlling growth-rate, the ecologic factors common to the entire reef tract should be ascertained, and each species should be studied to discover the subordinate ecologic conditions of its more restricted habitat. Investigations of the Florida reef tract along both these lines have been made, and the data are largely assembled preparatory to publishing them. Some of the results have been presented in my previous papers, and if space permitted they would be summarized here.

Observations and experiments were conducted on the growth-rate of Tortugas corals as follows:

(1) Colonies obtained from planulæ whose history is known. They were planted (*a*) off the northwest face of Fort Jefferson moat-wall; (*b*) on the reef off the northwest side of Loggerhead Key.

(2) Colonies cemented to tiles. Of these: (*a*) were planted off the northwest face of Fort Jefferson moat-wall; (*b*) on the reef off Loggerhead Key.

(3) Colonies naturally attached: (*a*) in Fort Jefferson moat; (*b*) on piers of the Fort Jefferson wharf; (*c*) on the outside of the northwest face of the Fort Jefferson moat-wall; (*d*) on the reef off the northwest face of Loggerhead Key.

The observations and experiments in the Bahamas were made on the leeward side of the north end of a small island, known as Golding Cay, which is on the east side of Andros Island at the mouth of South Bight. The specimens included: (*a*) those cemented to tiles and planted; (*b*) those living naturally attached.

The size of the colonies of all species of corals seems limited, but some attain large dimensions, 2 to 3 meters or even more in diameter, and nearly as

much in height, while other species are adult when a diameter of 35 to 50 mm. has been reached. Records of two species, *Favia fragum* and *Mæandra areolata* illustrate relatively rapid growth for the first 2 to 4 years, after which it decreases. Other species, for instance *Orbicella annularis* and *Mæandra strigosa*, are not so limited in size. Ramose corals increase in dimensions more rapidly than massive species; while of the former, the growth-rate of species with perforate, loose-textured skeletons is more rapid than that of those with dense skeletons. In general, the more massive and the denser the corallum, the slower the growth, while the more ramose and the more porous the skeleton, the more rapid the growth.

A few species will be specially considered.

Favia fragum (Esper).—The following table gives the size of colonies according to age. The average annual increment is indicated by the number preceded by the + sign below that for the average size. The average most rapid growth is during the first year, after which it declines, but should a specimen not attain an average size during the first year, it may grow rapidly during succeeding years until it catches up to the average. (Compare specimens Nos. 1 and 6 of the table.)

Favia fragum—averages according to age.

No.	1 year old.		2 years old.		3 years old.		4 years old.		5 years old.	
	Diam.	Height.	Diam.	Height.	Diam.	Height.	Diam.	Height.	Diam.	Height.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	11	4	27	8	30	11	30.5	11	......	......
2	12.5	4	22.5	7	25	10	26	11	......	......
3	19	6	31	11	33.5	13	34	13	......	......
4	19	5	29	11	32.5	14	33	16	......	......
5	19	4.5	31	11	36	14	41	17	......	......
6	5 5	5	17.5	8	26.5	13	32	16	38	20
[1]7	16	5	......	10.5	......	14.5	......	16	......	22
[1]8	13	3	......	9	......	......	......	......	......	......
9	9	2.5	19	7	20	9	21	11	......	15
10	10	2.5	17	10	26	......	29	10	33	13.5
11	8	2 5	11	4	......	......	......	......	......	......
12	.	....	...	......	26	......	31	......	34.5	......
13	9	....	20.5	8	23	11	......	......	......	......
14	13	....	20	8	......	......	......	......	......	......
15	18	....	23 5	9	27.5	12	31	15	39	16
16	11	....	25	9	27.5	11	32	14	36	16
17	10	....	16	9	......	......	......	......	......	......
18	9	....	11.5	6	17	10	......	......	......	......
19	10	....	16 5	5	19	6	......	......	......	......
20	12 5	....	15	......	17	......	......	......	......	......
21	18 5	....	18	5	......	......	......	......	......	......
22	6 5	....	15	......	......	......	......	......	......	......
23	9	....	19.5	10	23	11	......	......	......	......
24	12	....	24	......	27.5	12	26	14	......	......
25	9	....	21.5	9	25	12	27	15	......	......
26	10	....	15	......	19 5	......	29	......	......	......
27	16.5	....	22.5	6	23	......	......	......	......	......
28	12	....	18	7	22	......	28.5	......	28.5	......
29	17	....	23	7	26.5	......	31	......	33	18
30	11	....	13	3	......	......	......	......	......	......
Average..	11.93	4	20.01 (+8 08)	7.9 (+3.90)	25.14 (+5.13)	11.46 (+3.56)	30.13 (+4.99)	13.77 (+2.31)	34.71 (+4.58)	17.21 (+2.44)

[1]As 7 and 8 fused, separate measurements of the diameters became impracticable.

***Mœandra areolata* (Linn).**—The following table shows the decrease in growth-rate of *Mœandra areolata,* especially after a length of about 60 mm. has been attained:

Growth-rate of Mœandra areolata.

No.	Location of specimen.	Date.	Greater diameter.	Lesser diameter.	Height.	Remarks.
	Outside northwest face Fort Jefferson moat-wall:		*mm.*	*mm.*	*mm.*	
1	Tile 1*a*.....	June 7, 1910	9	7	12	1 yr. old.
		June 14, 1911	21 (+12)	13 (+6)	18.5 (+6.5)	2 yrs. old.
		July 7, 1912	37.5 (+16.5)	17-27 (+4, +14)	31 (+12.5)	3 yrs. old.
		June 3, 1913	47 (+9.5)	24-37 (+7, +10)	35 (+4)	4 yrs. old.
		June 19, 1914	55 (+8)	30-43 (+6, +6)	41 (+6)	5 yrs. old.
2	Tile 1*b*....	June 7, 1910	23	14	17	Probably 2 yrs. old.
		June 14, 1911	39.5 (+15.5)	28.5 (+13.5)	20 (+3)	Probably 3 yrs. old.
		July 7, 1912	55 (+15.5)	40 (+11.5)	31 (+11)	Probably 4 yrs. old.
		June 3, 1913	62 (+7)	....	31 (+0)	Probably 5 yrs. old.
		June 19, 1914	70 (+8)	52 (+12)	....	Probably 6 yrs. old.
3	Tile 1*g*	June 7, 1910	32	17	18	Probably 3 yrs. old.
		June 14, 1911	51 (+19)	35 (+18)	32 (+14)	Probably 4 yrs. old.
		July 7, 1912	65 (+14)	43 (+8)	35 (+3)	
		June 3, 1913	69 (+4)	48 (+5)	40 (+5)	
		June 19, 1914	73-75 (+4, +6)	52 (+4)	42 (+2)	
4	Tile 2*a*....	June 7, 1910	33	22	24	Probably 3 yrs. old.
		June 14, 1911	51 (+18)	41 (+19)	32 (+8)	
		July 7, 1912	60 (+9)	53 (+12)	38 (+6)	
		June 3, 1913	64 (+4)	59 (+6)	40 (+2)	
		June 19, 1914	65 (+1)	63 (+4)	40 (+0)	
5	Tile 2*b*. ...	June 7, 1910	46	17.5, 27	27	Probably 4 yrs. old.
		June 14, 1911	61 (+15)	33.5 (+16) 39 (+12)	38 (+11)	5 yrs. old.
		July 7, 1912	72 (+11)	50 (+16.5)	45 (+7)	6 yrs. old.
		June 3, 1913	80 (+8)	55 (+5) 58 (+18)	48 (+3)	7 yrs. old.
		June 19, 1914	84 (+4)	62 (+7) 64 (+6)	53 (+5)	8 yrs. old.
8	Tile 4*b*	June 7, 1910	92	50	40	
		June 14, 1911	93 (+1)	54 (+4)	40 (+0)	Spec. healthy but had not grown.
		July 7, 1912	99 (+6)	57 (+3)	40 (+0)	
		June 3, 1913	100 (+1)	57 (+0)	48 (+8)	Tops partly buried by silt, etc.; not used in computing averages.
9	Tile 4*c*... ..	June 7, 1910	72	52	37	
		June 14, 1911	79 (+7)	53.5 (+1.5)	41 (+4)	
		July 7, 1912	80 (+1)	55 (+1.5)	41 (+0)	Tops partly killed by silt, etc.
		June 3, 1913	80 (+0)	55 (+0)	44 (+3)	Not used in computing averages.

Siderastrea radians (Pallas).—The following gives the diameters of two colonies according to age:

	No. 1.	No. 2.
	mm.	*mm.*
One year old.........	....	11
Two years old........	15	17
Three years old......	22.5	26
Four years old.......	30	..

Porites astreoides Lam.—The following table gives the size of young colonies of *Porites astreoides* according to age:

No.	1 year old.		2 years old.		3 years old.		4 years old.		5 years old.	
	Diam.	Height.	Diam.	Height.	Diam.	Height	Diam.	Height.	Diam.	Height.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	12.25	.....	35	12	43.5	20	59.5	39	75	54.5
2	11.75	.....	32	.....	37	......	41.5	......	54.25	......
3	9.00	2 or 3	23	6	29	10	46.75	18	54	21
4	18.75	3	38.5	10	53.5	12	89.5	23	99.75	31
5	16.25	.....	34.23	.....	41	......	54	......	66.75	......
6	10.5	.....	31.5	......	38	......	41.75	......	48 50	......
7	16.5	....	31	.....	45	.....	50.50	......	68.25	......
8	10 75	..	24 5	....	25	10	28	17	35 50	21
9	6.25	.....	18 5	......	26.5	7	35.5	13.5	53	21
10	8 5	..	18	.....	24.5	5	....	9	41	......
11	7.75	..	18 5	..	26	.....	.....	....	....	....
12	18.5	..	42	7	52.50	8	62.50	13	75.50	18
13	10.75	.	21	.	35 5	....	51.75	......	65.50	...
14	15.75	....	30	.	39.5	......	44.5	......	55.50	......
15	.....	....	.....	......	......	......	47	......	64.50	......
Av	12 375	3	28.41 (+16.035)	8.75 (+5.75)	36.89 (+8.48)	10 28 (+1.53)	50.21 (+13.32)	18.92 (+8.64)	61.21 (+11.00)	27.75 (+7.83)

When practicable two diameters at right angles to each other were measured in successive years, and the increments were ascertained by subtracting the preceding from the later measurements. All increments for each species at each station were added together and divided by the number of the annual increments entering into the computation. The averages for height were similarly determined. As the records are for annual growth-rate, each of the Bahama records is counted as two, as each of those records represents a period of two years.

It should be said regarding the nomenclature of the species that the specimens designated *Mussa* (*Isophyllia*) *dipsacea* Dana may include colonies of *M.* (*Isophyllia*) *fragilis* Dana. The specimens referred to *Porites clavaria* Lamarck may include more than one species of similar growth facies.

Indicated average annual growth-rate of Floridian and Bahaman shoal-water corals.

[NOTE.—Nat. att. = naturally attached. Note 1 in table, accuracy of record doubtful; note 2, tape-line measurements, accuracy somewhat doubtful.]

Name and station.	Increase in diameter.		Increase in height.	
	Amount.	Number of records as basis for estimate.	Amount.	Number of records as basis for estimate.
Oculina diffusa Lam.:	*mm.*		*mm.*	
Fort Jefferson, tiles outside moat wall.....	19.28	7	7.5	2
Fort Jefferson, moat, nat. att..	19.25	4	12.70	5
Fort Jefferson, wharf, nat. att....	29 57	28	22.61	13
Eusmilia fastigiata (Pallas):				
Fort Jefferson, tiles outside moat wall....	9 61	22	4.5	10
Fort Jefferson, wharf, nat. att...........	10 62	19	7	4
Loggerhead Key, reef, nat. att...... .	21	1	.....	..
Dichocœnia stokesi, M.-Ed. & H.:				
Fort Jefferson, moat, nat. att.....	6.67	12	[1]5.2	..
Golding Cay, tiles....	6 29	24	2.2	10
Golding Cay, nat. att.	2	4	2	2
Dendrogyra cylindrus, Ehr.:				
Golding Cay, tiles......	7	16	10 375	8
Orbicella annularis (Ell. & Sol.):				
Fort Jefferson, tiles outside moat wall....	7.43	29	6 57	14
Loggerhead Key, reef, tiles	6 89	29	5.28	14
Loggerhead Key, nat. att. . .	9.02	36	6.80	5
Golding Cay, tiles	6 45	24	5.67	12
Golding Cay, nat. att.	0	2	5	2
Orbicella cavernosa (Linn.):				
Fort Jefferson, tiles outside moat wall...	14.50	19	3.22	9
Loggerhead Key, reef, tile....	4.83	6	5.67	3
Golding Cay, tile	9 5	4	3.5	2
Favia fragum (Esper)				
Fort Jefferson, tiles outside moat wall.. .	4.42	27	2.92	14
Fort Jefferson, moat...	4.2	27	3 77	11
Fort Jefferson, outside moat wall, nat. att.	6.417	6	.....	..
Loggerhead Key, reef, nat. att...... .	4 5	8	5 00	1
Golding Cay, tiles	3.62	24	3.83	12
Manicina gyrosa (Ell. & Sol.):				
Fort Jefferson, tiles outside moat wall.....	9.75	4	2.5	2
Loggerhead Key, reef, tiles........... .	7.87	12	4.67	6
Fort Jefferson, moat (transplanted)..... .	21.50	6	8.67	3
Fort Jefferson, wharf	16 77	22	7.00	4
Mæandra areolata (Linn.):				
Fort Jefferson, tiles outside moat wall. ...	10.74	66	6.71	28
Fort Jefferson, moat (transplanted).......	15.25	12	9.60	5
Fort Jefferson, outside moat wall, nat. att	12.00	4	.....	..
Golding Cay, tiles....	7.34	26	3.64	14
Mæandra labyrinthiformis (Linn.):				
Golding Cay, tiles	9.17	24	4.92	12
Golding Cay, nat. att	6.375	8	7.50	2
Mæandra strigosa (Dana):				
Loggerhead Key, reef, tile..	7.70	5	5.33	3
Fort Jefferson, moat, nat. att......... ...	19.80	5	10.00	3
Fort Jefferson, wharf...................	11.17	6	3.50	2
Loggerhead Key, reef, nat. att..	9.75	8	8.75	4
Golding Cay, tiles.................. .	8.14	24	4.60	12
Golding Cay, nat. att..................	5.92	14	7.50	6
Mæandra clivosa (Ell. & Sol.):				
Fort Jefferson, tile, outside moat wall.....	20.90	10	8.83	6
Loggerhead Key, reef, tiles.............	9.41	18	4.72	9
Fort Jefferson, moat, nat. att............	24 14	35	5.57	7
Fort Jefferson, wharf, nat. att...........	14.91	12	4.00	1
Golding Cay, tiles....................	5.25	4	2.50	2
Golding Cay, nat. att..................	7.67	12	.....	..

Indicated average annual growth-rate of Floridian and Bahaman shoal-water corals—Con.

[NOTE.—Nat. att. = naturally attached. Note 1 in table, accuracy of record doubtful; note 2, tape-line measurements, accuracy somewhat doubtful.]

Name and station.	Increase in diameter.		Increase in height.	
	Amount.	Number of records as basis for estimate.	Amount.	Number of records as basis for estimate.
Mussa (Isophyllia) dipsacea Dana:	*mm.*		*mm.*	
Golding Cay, tiles	6 04	24	3.33	12
Golding Cay, nat. att	0	2	5	2
Mussa (Isophyllia) rigida Dana:				
Golding Cay, tiles	2.56	[1]16	1.13	8
Golding Cay, nat. att	6.75	12	2.75	4
Siderastrea radians (Pallas):				
Fort Jefferson, tiles, outside moat	3.31	29	2.37	15
Loggerhead Key, reef, tiles	2.13	4	1.5	4
Fort Jefferson, moat, nat. att	7.59	24	.....	..
Golding Cay, tiles	2.50	8	2.13	4
Golding Cay, nat. att	0.00	8	0.00	4
Siderastrea siderea (Ell. & Sol.):				
Fort Jefferson, tile, outside moat wall	7.71	7	2 67	3
Loggerhead Key, reef, tiles	3.75	4	4.16	3
Loggerhead Key, reef, nat. att	7.41	12	5.00	1
Golding Cay, tiles	5.05	20	2.70	10
Golding Cay, nat. att	4 38	8	2.50	2
Agaricia agaricites (Linn.):				
Golding Cay, tiles	6.94	18	5.50	10
Agaricia purpurea LeS.:				
Fort Jefferson, tiles, outside moat wall	5 67	37	3 76	17
Fort Jefferson, from planulæ nat. att. to tiles	8.33	6	..	..
Fort Jefferson, wharf, nat. att	17.25	8	.....	..
Loggerhead Key, reef, nat. att	4.84	16	.....	..
Agaricia crassa Verrill:				
Golding Cay, tiles	2.25	8	6.50	4
Acropora cervicornis (Lam.):				
Fort Jefferson, tiles, outside moat wall	51.72	27	40.00	12
Golding Cay, tiles	.. ..	..	45.33	6
Acropora prolifera (Lam.):				
Golding Cay, tiles	44 50	18	37.17	6
Acropora palmata (Lam.):				
Golding Cay, tiles	49.87	24	25.00	16
Golding Cay, nat. att	[2]95.36	8	39.50	2
Porites clavaria Lam.:				
Fort Jefferson, tiles, outside moat wall	20.19	50	20.45	21
Fort Jefferson, moat, nat. att	39.40	10	20.20	5
Fort Jefferson, wharf, nat. att	18 50	4	15.50	2
Loggerhead Key, reef, nat. att	35 00	4	22.00	1
Golding Cay, tiles	18.06	42	20.25	32
Golding Cay, nat. att	6 93	16	8.33	6
Porites furcata Lam.:				
Fort Jefferson, tiles, outside moat wall	32 13	33	17.00	18
Fort Jefferson, moat, nat. att	39 27	42	22.80	18
Fort Jefferson, wharf, nat. att	44.75	4	16.00	2
Fort Jefferson, outside moat, nat. at	31 50	2	9 00	1
Porites astreoides Lam.:				
Fort Jefferson, tiles, outside moat wall	16.19	34	5.70	15
Fort Jefferson, moat, nat. att	23.05	18	6.22	9
Fort Jefferson, wharf, nat. att	14.00	2	14.00	1
Fort Jefferson, outside moat wall, nat. att.	13.11	9	.....	..
Loggerhead Key, reef, nat. att	10.60	25	13.28	7
Golding Cay, tiles	3.50	16	3.50	8
Golding Cay, nat. att	7.56	16	8.75	4

As has been stated, the primary object of this investigation was to get an approximate measure of the rate at which corals might build reefs. In order to make this estimate the true reef corals must be considered separately from those which live in other habitats. The reef species par excellence in the Recent and Pleistocene reefs of Florida and the West Indies is *Orbicella annularis;* after it in importance are *Mœandra strigosa, M. labyrinthiformis,* and *Siderastrea siderea.* Other corals, the most important of which is *Porites astreoides,* with *Agaricia* and *Favia fragum* of secondary importance, occur in the areas intermediate between the prominent heads. In some areas *Acropora palmata* is the dominant species. The massive heads form the strong framework of the reef, with infilling by other corals and other organisms. Therefore the upward growth rate of *Orbicella annularis* on the reef is critical. The data on it will be repeated:

Upward growth-rate of Orbicella annularis.

Location.	Annual average.
	mm.
Fort Jefferson, tiles, outside moat wall...	6 57
Loggerhead Reef, tiles................	5.28
Loggerhead Reef, naturally attached.. ..	6 80
Golding Cay, tiles	5.67
Golding Cay, naturally attached.... ..	5 00

The highest figure is for naturally attached specimens on Loggerhead Reef, but the average is based on only 5 measurements, which are not so accurate as those of specimens on tiles. The specimens attached to tiles all thrived and gave an annual average of 5.28 mm. for 14 measurements; while the Golding Cay specimens, which also thrived, gave an annual average of 5.67 mm. for 6 specimens, 2 years' growth each. An estimate of 6 mm. for upward growth per year is probably somewhat liberal. This would indicate for an upward growth of a foot, $\frac{24.5 \times 12}{6} = 50.8$ years. Should 7 mm. be taken as the average the rate would be 1 foot in 43.54 years. Using these figures as the basis of a further computation, a reef by the continuous upward growth of corals might attain at a rate of 6 mm. per year a thickness of 25 fathoms = 150 feet in 7,620 years; and at a rate of 7 mm. per year it might attain the same thickness in 6,531 years.

Should the growth-rate of *Acropora palmata* be taken as a measure, the time to accumulate such a thickness would be considerably less. This species forms spreading, palmate fronds, rising from stout bases. As age advances the fronds thicken and can withstand the pounding of surf and breakers. The average upward growth is between 25 and 40 mm. per year, but as the interspaces between the fronds are considerable in volume, comparisons with *Orbicella annularis* must be based upon relative increases in weight for a known period. The tables on page 234 will supply such a basis:[1]

According to weight, the specimens of *Acropora palmata* have grown 3.91 times as fast as those of *Orbicella annularis;* this may be stated in round numbers as 4 times as rapidly, while the increase in height is 4.28 times as rapid. Therefore a reef composed of *Acropora palmata* might grow upward at the rate of about an inch per year, a growth which would produce a thickness of 150 feet in $150 \times 12 = 1{,}800$ years, but it is not probable that conditions so

[1]The weights are of the wet, living corals.

favorable have ever been realized in any area for a protracted period. These two estimates give a measure of the limits of reef formation under continuously favorable conditions for upward growth. Such corals as *Orbicella annularis* might form a reef 150 feet thick in between 6,500 and 7,600 years; while such corals as *Acropora palmata* might form a similar thickness in 1,800 years.

Growth-rate of Orbicella annularis.

Location and date.	Tangential diameter.	Radial diameter.	Height.	Weight.
Golding Cay, tile 1:	*mm.*	*mm.*	*mm.*	*gm.*
May 11, 1912.......	46	44	43	67
May 10, 1914.......	50 (+ 4)	52 (+ 8)	56 (+13)	104 (+ 37)
Golding Cay, tile 2:				
May 11, 1912	49	43	52	94
May 10, 1914......	58 (+ 9)	52 (+ 9)	67 (+15)	197 (+103)
Golding Cay, tile 3:				
May 11, 1912... ..	62	52	64	217
May 10, 1914......	81 (+19)	70 (+18)	75 (+11)	435 (+218)
Golding Cay, tile 4:				
May 11, 1912. ...	109	75	74	566
May 10, 1914......	121 (+12)	81 (+ 6)	79 (+ 5)	729 (+163)
Golding Cay, tile 6:				
May 11, 1912	140	90	77	942
May 10, 1914. . ..	158 (+18)	117 (+27)	90 (+13)	1,525 (+593)

Total of the weights of 5 specimens in 1912, 1,886 grams; total increase in weight of the 5 specimens in 2 years, 1,114 grams, or $\frac{1114}{1886}$ = 59.1 per cent. The average annual increase in height of these specimens is 5.7 mm.

Growth-rate of Acropora palmata.

Location and date.	Tangential spread.	Radial spread.	Height.	Weight.
Golding Cay, tile 33:	*mm.*	*mm.*	*mm.*	*gm.*
May 11, 1912....	....	78	111	250
May 10, 1914.. .	....	237 (+159)	158 (+47)	670 (+420)
Golding Cay, tile 34:				
May 11, 1912.. ..	. .	69	89	59
May 10, 1914 ...	....	187 (+118)	124 (+35)	295 (+236)
Golding Cay, tile 35:				
May 11, 1912.....	....	65	109	98
May 10, 1914 .	....	230 (+165)	171 (+62)	480 (+382)
Golding Cay, tile 38:				
May 11, 1912....	76	42	104	275
May 10, 1914 ..	136 (+ 60)	86 (+ 44)	118 (+14)	437 (+152)
Golding Cay, tile 39:				
May 11, 1912 ...	78	34	82	163
May 10, 1914.....	193 (+115)	148 (+114)	178 (+86)	700 (+537)

Total of the weights of 5 specimens in 1912, 745 grams; total increase in weight of the same 5 specimens in 2 years, 1,727 grams, or $\frac{1727}{745}$ =231.8 per cent. Average annual increase in height of these specimens 24.4 mm.

A few references to previous literature will indicate the rate of growth of Pacific and Indian Ocean corals.

H. B. Guppy[1] has furnished interesting data on the rate of growth of corals around Keeling Atoll, including in his account the results of some experiments

[1]Scottish Geograph. Mag., vol. 5, 1889, pp. 573–576.

by G. C. Ross. According to Guppy, arborescent acropores "grow at the average rate of 4 to 5 inches in a year, and will attain their full height in about fifteen years." He estimates that branching species of *Porites* grow upward at the rate of 1.5 inches per year, while the annual upward growth of massive species of *Porites* is from 0.5 to 0.75 inch per year. *Montipora*, of the facies of *M. digitata*, is said to have an upward growth of not less than 5 inches per year.

J. Stanley Gardiner and F. Wood-Jones have made valuable contributions to the knowledge of the growth-rate of Indo-Pacific corals. Wood-Jones has summarized the data in a privately published paper entitled, "The rate of growth of reef building corals." His observations in Cocos-Keeling Islands corroborate the estimates of Guppy. According to his recomputation of the data supplied by J. Stanley Gardiner, based on a collection of presumably 3-year-old corals from Hulule, North Male Atoll, a general average of the upward growth for branching forms is about 44 mm. per year, while that of massive forms is about 29 mm. J. Stanley Gardiner's estimates for the massive forms would be as follows:

Forms.	Growth per year.
	mm.
Massive Astreidæ ..	22
Massive Fungidæ. .	29
Massive Perforata...	20 3

As it is probable that these corals, especially the massive ones, are more than 3 years old, I am inclined to the opinion that the estimates for the massive species are too high. Guppy's estimate of the upward growth of massive *Porites*, 12.7 to 19.05 mm. per year, seems better founded and falls within the range of a number of the measurements on *Porites astreoides*.

Recent remeasurements by Mayer of some of the corals measured and marked by Saville-Kent at Vivien Point, Thursday Island, Torres Straits, Australia, indicate an annual increase in diameter of 1.9 inches per year. As in massive corals the increase in height is usually one-half to two-thirds that in diameter, the increase in height would probably be between 24 and 32 mm. per year, or approaching the figures given by J. Stanley Gardiner and F. Wood-Jones for massive forms.

The data available for the Pacific corals are not so abundant as those for the Atlantic, nor have the records, with few exceptions, the same degree of precision. However, they are sufficient for some general comparisons. The general growth-rate of branching corals is nearly the same for both regions; but the growth of the massive forms in the Pacific appears to be appreciably more rapid than that of similar forms in the Atlantic. Therefore, it seems probable that in the coral-reef regions of the Pacific and Indian Oceans a reef 150 feet thick may form under favorable conditions in less than 6,000 years. According to Gardiner such a reef might form in 1,000 years.

As the disappearance of the last continental ice sheets is estimated to have been between 10,000 years ago in Scandinavia and Alaska and 40,000 years ago at Niagara, the data presented show that there has been ample time for the development of any known living reef since deglaciation. That recent offshore reefs have been formed either during or immediately subsequent to Recent submergence may be accounted established. That deglaciation was an important factor in this submergence can scarcely be doubted, but there are other factors which have not yet been evaluated.

Geologic Investigations of the Florida Coral Reef Tract, by Thomas Wayland Vaughan and Eugene Wesley Shaw.

The investigations of the geology and geologic processes of the Florida reef and key region were continued along lines followed by Vaughan during seven preceding seasons. Additional bottom samples were collected, especially around Tortugas and between Key West and Marquesas. These samples are being studied to ascertain the proportion of calcium carbonate contributed by different agencies, the processes whereby ingredients other than calcium carbonate are added to the bottom material, and the factors controlling the distribution of material according to size. All of these are subjects of prime importance in understanding phenomena associated with coral reefs.

Shaw resurveyed Loggerhead Key, using the same scale as Vaughan did in 1914. He also made plane-table surveys of Bird, Long, Bush, Sand, Middle, and East Keys, and indicated the position of the present shore-line on the large-scale map of Garden Key. Comparison of these maps with those made by the Coast and Geodetic Survey during previous years shows that the forms and even the positions of the keys are continually being changed, though the rate varies greatly from time to time and from key to key. A sufficient body of data has now been accumulated to serve as a basis for describing the modifications in the key outlines and for referring the modifications to their causes. The current records made in 1914 and the records of the wind movement by the U. S. Weather Bureau are essential parts of this information

Other problems received attention, but it is not practicable to present the results in a form sufficiently succinct for this Year Book. For example, attention was given to the slopes of the beaches and their controlling factors, the sizing of the sands composing the keys, the reason why the outer border is commonly higher than the interior portions of the keys, the question of submarine destruction of calcium-carbonate structures by different agencies and the part they play in the development of sea-bottom forms, the transportation of chemically precipitated sediment which is taking place on a large scale, the stage of the Tortugas in the cycle of their history, the composition of water in Biscayne Bay and in the Everglades, the pitting of limestone along the seashore, the interpretation of the channel forms of Miami and other rivers, and estimates of the ages of the various physiographic features both in years and in the cycle of their existence.

Areal Geology.

Additions to the knowledge of the areal geology of the region were made between Key West and the western margin of Marquesas. Oolitic limestone was found between Key West and Boca Grande on West Crawfish, Barracouta, Woman, and Man Keys. Except these exposures of indurated oolite, the bank between Key West and Boca Grande channels is composed of calcareous mud, overlying hard rock, which ranges in position from low-tide level to 10 feet below that datum. Many soundings through the mud in the Marquesas lagoon showed the rock surface to lie from 9 to somewhat more than 12 feet, generally about 12 feet, below low-tide level. Vaughan had previously found one locality at which the rock is 15 feet below low tide, with 15 feet of mud over it. The mud ranges in thickness from 4 to 15 feet—for the most part 8 to 10 feet. A pipe was driven into the rock below the mud near the west end of Conch Key and a core of indurated oolite was obtained, thus confirming Vaughan's published deduction, from finding hard oolite grains in Marquesas bottom samples, that the foundation of the Marquesas is oolite. How far westward of the Marquesas the oolite extends is not known, but it appears safe to assume that it underlies at least the eastern part of the Quicksands and it may extend to Half Moon Shoal and even to Rebecca Shoal.

Oscillation of the Florida Coral Reef Tract.

As in the opinion of many students of the coral-reef problem, the essential part of the coral-reef theory lies in the relation developing reefs bear to changes in position of sea-level and in the rôle played by corals as constructional geologic agents, these two subjects should receive particular attention from all investigators of the problem. The former subject for the Florida area will here be dealt with in detail, and the latter briefly considered. The latter has received much attention from Vaughan, and additional information is given in Vaughan's report in this Year Book.

The oscillations of the Florida reef tract have been discussed in most detail by Sanford and Vaughan. According to the latter, who has summarized the data accumulated by Sanford and himself, also those gathered farther north in the peninsula by Matson, Clapp, and others, the character of the Florida coast-line shows that the last important movement of the peninsula was downward, that the keys participated in the uplift and subsequent depression that affected the mainland, that they at one time stood more than 30 feet higher than they now do, and that this uplift and subsequent depression, according to all available evidence, extended to the Tortugas.[1] In the last Year Book of this Institution, p. 232, Vaughan stated regarding the Tortugas:

> "Studies of the bank around Loggerhead Key showed the bottom to be composed of rock, which is frequently bedded, and whose surface is pitted, jagged, cavernated, and tunneled, with a zone of undercutting, the upper edge of which ranges in depth from 16 to 24 feet . . . previous observations combined with additional somewhat casual observations strongly suggest submerged surfaces which were sculptured at or above the reach of the waves, while wave-cut cliffs occur at lower levels"

In the same Year Book he pointed out evidence of minor uplift subsequent to submergence in the vicinity of Miami. Bearing in mind the previous work, an endeavor was made to procure as much supplemental information as possible and all evidence was critically reviewed. As lands of low relief and underlain by porous and easily soluble limestone, such as southern Florida, do not have conspicuous valleys, no assistance in interpreting oscillations was expected from this class of phenomena. The lines of evidence found usable were (1) scarps and terraces, both above and below sea-level; (2) submerged solution wells and caves; (3) submerged peat deposits; (4) submerged indurated rock.

The physiography of the land and sea-bottom in the vicinity of Miami were studied in considerable detail. The following will give an idea of the features there exhibited: (1) An upland plain stands at an altitude of 17 to 20 feet, and in South Miami is separated from the next lower plain by a sea-cut escarpment, approximately 10 feet high. (2) This next lower plain is the one on which most of the city of Miami is built. The general altitude of its surface is about 8 feet, but it rises toward Biscayne Bay and in Palm Park a part of it is between 10 and 11 feet. The gentle rise is probably due to an old beach ridge. This plain occurs at the base of the scarp in South Miami and is separated by an obscure scarp from the next lower terrace. (3) The third terrace from the top should perhaps be grouped with the second. The altitude of its surface is between 4 and 5 feet, and it stands above a lower bench (4) which has an altitude of 1 to 2 feet.

Miami River has trenched its channel into the Miami oolite to a depth of about 18 feet below sea-level.

Borings in Biscayne Bay, to ascertain the nature of the foundation for piers, have revealed the presence of a terrace east of Miami 10 feet below low tide. The records of these borings were reported by Mr. John Mills, engineer of the *Anton Dohrn*. The submerged terrace extends across Biscayne Bay, and upon its surface has been built the sand spit on the east side of the bay.

[1] Jour. Wash. Acad. Sci., vol. 4, p. 29, 1914; Carnegie Inst. Wash. Pub. No. 182, pp. 63–65, 1914.

Borings made by Mr. Mills, for the Florida East Coast Railway, between the lines of Fourth and Tenth streets extended, to a distance of 1,700 feet off the point of the Terminal dock, showed a rock floor at a depth of 10 feet below low tide, but narrow, well-like holes over 35 feet deep and filled with mud and sand were found in several places, indicating the presence of solution wells in the oolite. In a group of several holes, the drill after penetrating 4 feet of rock, at a depth of 14 feet below the water-level, dropped 14 feet, and no washings were obtained from this interval. This is evidently a cave having a roof of 14 feet and a floor 28 feet below sea-level.

The freshness of the elevated scarp in South Miami supports the inference that the last movement was one of elevation of 10 feet. If this inference is correct, the evidence indicates that the surface about Miami, after being below sea-level, was elevated by stages to a position 55 feet above sea-level, then was depressed 46 feet, and finally elevated at least 10 feet, resulting in the land surface still standing 36 feet lower than previously.

The scarp in South Miami was traced to the Punch Bowl, thence through Cocoanut Grove and southwestward to Cutler. Southward from the Punch Bowl the surface of the lowest terrace is occupied by a marsh or swamp extending along the bay front. Southwest of Cutler the scarp decreases in height until at 3.3 miles southwest it is not marked; 3.75 miles south of Cutler, swamp appears on the oolite surface, and the scarp has disappeared though the pine forest characteristic of the upland persists. The elevation in Miami has been accompanied by local warping, but this was not sufficient in amount to offset the antecedent dominant submergence.

Shaw critically examined the submerged scarps around Tortugas with the object of testing Vaughan's suggestion that they were due to marginal marine cutting. These submerged terraces, and particularly the remarkable front of a terrace lying 15 or 20 feet below sea-level, are the most important of the lines of physiographic evidence of subsidence in the vicinity of the Tortugas. This front is an undercut cliff and apparently differs in no essential respect from the cliffs which are being formed to-day along the shore of southern Florida, where the sea is cutting into a low-lying limestone area of land.

The only other tenable hypotheses for the origin of these submerged undercut cliffs are, first, that they are due to some remarkable combination of rock hardness and current work; second, that they have been produced by the growth of corals. The first hypothesis seems to be inapplicable (*a*) because the submerged cliffs, though in detail intricately irregular, display in a broad way the sweeping curves characteristic of shore-lines, are perpendicular to the general slope of the bottom, and the cliffs are accordant in depth; (*b*) because the sea-floor does not display the mushroom-like forms of all manner of size and distribution which would result from the erosion of two hard layers separated by a soft one; (*c*) Shaw, using diving apparatus, examined the rock in the reentrant and found it as resistant apparently as that above and below. The objection to the second hypothesis is that although coral skeletons are very abundant on the edge of the overhanging cliff, as might be expected, because such a cliff forms a very favorable place for corals to grow, other kinds of rock are also present and the resulting feature does not have the form of a coral stack, though coral stacks are present in the region. How extensive the non-coral rock is can not now be stated, because of the difficulty in obtaining samples. Some samples of Texas rock and of the rock at the edge of the cliff 0.5 mile north of the Tortugas laboratory were, however, obtained.

Where the scarp is not covered with sand the surface just back of the top of the cliff shows the deep pitting with many little channels and bores characteristic of limestone cliffs along the present coast. The rock is stratified and shows everywhere both large and small pits of extremely irregular form, such

as characterize limestone surfaces now exposed. Along the edge of the submerged cliff are also features somewhat like small stream-cut gullies but unlike them in being of irregular depth and width, in these respects resembling the features produced by wave attack where the effect is locally concentrated. In places, as for example just west of Bird Key, are larger features strongly suggesting deep, narrow, branching valleys. Other forms characteristic of land areas were sought, but none was found and probably none should be expected.

Mr. Hector von Bayer, engineer and architect of the U. S. Bureau of Fisheries, who has charge of the installation of the Bureau of Fisheries Station at Key West, has supplied detailed information on an extensive bed of submerged peat, encountered in dredging a channel to the site of the laboratory. He has given us the following statement:

"In response to your request for data on the geologic formations encountered while excavating a channel 6 to 7 feet deep at mean low-water and 30 feet wide, leading from off-shore between the western end of Cow Key and Key West Island to the site of the marine biological laboratory of the Bureau of Fisheries, a distance of about 1.12 nautical miles, I beg to state as follows:

"So-called marl, full of small shells, was generally found at the bottom in 1 to 2 feet of water at mean low tide, with underlying hard oolitic rock, having a flint-like crust; the rock was also frequently encountered bare at that depth. The marl ranged in thickness from 1 to over 3 feet. In a number of places, from 300 to 500 feet in length, it was bedded on strata of peat overlying and apparently filling depressions in the surface of the oolite. The peat ranged from 1 to over 4 feet in thickness, and extended to more than 8 feet below sea-level."

Later we lent Mr. von Bayer a mud sampler for sounding the peat, and he reported his results, as follows:

"*a.* In channel, water 7½ feet deep at m. l. t., excavated through 2 feet of marl overlying peat. Bottom of the peat at three localities respectively 10.5, 12, and 13 feet below m. l. t.

"*b.* 100 feet west of the preceding, water 1 foot 9 inches deep, marl 2 to 6.5 feet deep, hard rock at 7 feet, no peat."

The accompanying figure shows the precise position of the borings into the peat and a diagrammatic section at the locality.

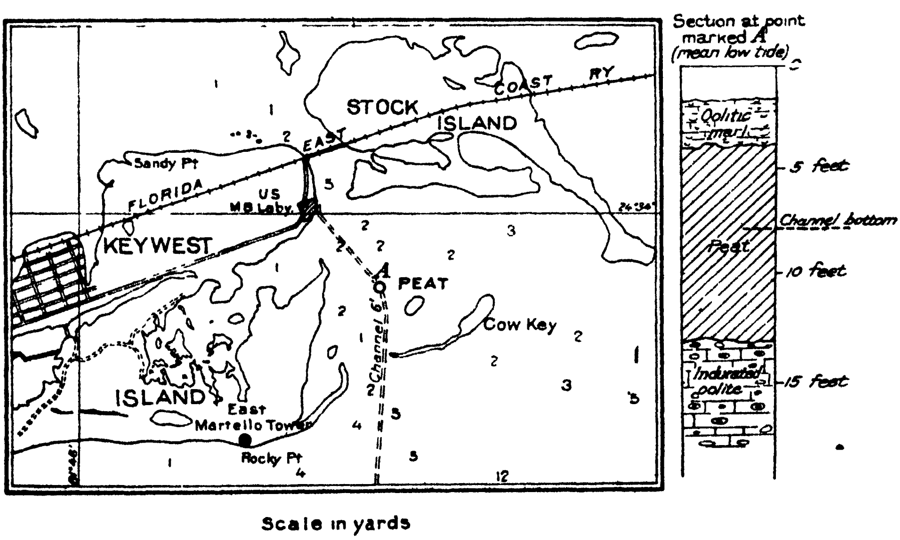

FIG. 1.—Soundings in feet, mean low water. Map traced from U. S. C. and G. chart No. 584.

The upper surface of the oolite has a crust precisely similar to the incrustation usual on the rock subaërially exposed. In fact this crust is apparently as significant and as definite evidence as is the submerged peat.

Mr. H. L. Cook, a contractor formerly with the Florida East Coast Railway, reports that near Harris Key, north of the town of Chase, on Sugarloaf Key, submerged peat was found 6, 14, and 18 feet thick, overlain by marl, and underlain by solid rock. Submerged peat is reported at other localities, one of them being Big Coppit Key. As this peat, of course, could not have been formed in the sea at depths exceeding a foot or two, its meaning as to submergence is incontrovertible.

Another line of evidence utilized was the relative induration of the rock. It is established that calcareous sand and mud when exposed to atmospheric agencies and between tides commonly become indurated, whereas from present evidence it seems that such induration does not take place on the sea-bottom. For instance, oolitic muds remain soft and incoherent on the sea-bottom, but when lifted above water-level they become hard. An excellent instance of subaërial induration was seen about 2 miles south of Fort Lauderdale, on the side of the road to Miami, where there is an elevated beach ridge composed of hard oolite. Not only the general form of the beach is preserved, but its seaward and landward slopes are as easily identified as those of a present-day beach ridge. Vaughan has already based deductions on this kind of evidence in discussing changes of level in the Tortugas, where from the presence of submerged beds of indurated detrital limestone he inferred a lowering of the land surface.

The occurrence of submerged indurated oolite beneath Biscayne Bay, beneath the peat beds between Sugarloaf Key and Key West, below the covering of mud on the bank between Key West and Boca Grande Channels, and beneath the mud in Marquesas, has been mentioned. The specimens from Marquesas have the same aspect as the subaërial oolite on Key West, the matrix of some of the grains having undergone secondary crystallization. The deduction from the induration of the submerged oolite is the same as that from the submerged scarps, solution wells, caves, and peat beds, viz, that the last dominant change in position of sea-level was one of submergence.

There appears to have been a tilting or warping of the reef tract during and perhaps subsequent to this submergence, for the general southwestward slope of the bottom is better explained by tilting than by gradation. Vaughan has several times pointed out that most of the Florida barrier reef stands on the seaward margin of a submerged terrace which extends northward beyond the reef limits. Hawk Channel lies along this terrace between the barrier reef and the main line of keys. Off Miami the maximum depths within the reef line are only about 5 fathoms. In tracing the surface westward to Rebecca Shoal it is found to deepen slightly. Between Key West and Boca Grande Channels depths of 8.5 fathoms are attained; south of the Quicksands the depths are as great as 9, 10, and 11 fathoms, while farther west the maximum depths in the Tortugas Lagoon is 13 fathoms. The tilting or warping of the upper terrace surface southwest of Miami, which has been mentioned, the restriction of the subaërial surface between Key West and Boca Grande Channels, and the disappearance of subaërially exposed oolite west of Boca Grande are all in accord with greater submergence toward the west, as suggested by tracing the floor of Hawk Channel. This conclusion also accords with that reached from the more extensive studies of the geology of the peninsula, which is that there has been a slight general westward tilt of southern Florida.

Additional deductions of importance may be made from the submarine physiography at depths beyond 10 fathoms, and although the investigations are at present only in a preliminary stage, it may be said that along the sides of the Gulf Stream, from opposite Miami to Satan and Vestal Shoals, just west of Sand Key, the Coast and Geodetic Survey charts indicate fairly uniform slopes from 10 to 100 fathoms, but there may be narrow terraces which are

not brought out by the soundings. West of Vestal Shoal the sea-bottom drops suddenly from 10 to 20 fathoms, with a flat or gently sloping surface between 20 and 28 fathoms. South of Coalbin Rock there is an escarpment between 10 and 30 fathoms, a flat or gentle slope between 30 and 40 fathoms, and another flat or gently sloping area between 40 and 50 fathoms. The soundings are not sufficiently numerous to trace surfaces with a feeling of confidence, but the scarp from 10 to between 25 and 30 fathoms is clear cut and can be followed for 25 miles to the west end of the Quicksands. Westward, in the vicinity of Tortugas, besides the bottom of Tortugas Lagoon and the surface of the shoal 7 to 10 miles west of Loggerhead Key, there are two undersea terrace plains; one is at a depth of 15 to 17 fathoms; the other (which is a large plain west of the Tortugas) ranges in depth from 28 fathoms on its landward to 36 fathoms on its seaward edge and has an east-and-west width of 10 miles. The 15 to 18 fathom flat is especially well developed south and southwest of the Tortugas. It is separated by a scarp from the 28 to 36 fathom flat, and by another scarp from the shallower levels in the Tortugas.

The presence of the continuous scarp from Coalbin Rock to a point off the west end of the Quicksands, with a depth of 25 to 30 fathoms at its base, and the presence of a terrace flat 28 to 36 fathoms deep, 10 miles wide, and bounded on its landward margin by a similar scarp, suggest that the portion of the Florida reef tract west of Key West at one time may have stood some 20 fathoms higher than now; while the 15 to 18 fathom terraces suggest another, shallower stand of sea-level.[1]

Although the tracing of the oscillations of the Florida reef tract can not now be made in detail, it seems probable that the tract at one time stood more than 120 feet higher than at present, and in the submergence which has followed the land area has been greatly reduced. Besides the problematic larger swing, there have been intermediate stands of sea-level and numerous minor oscillations. The last movement of importance was one of submergence, but subsequent to it there has been a minor uplift of some 10 feet or slightly more in the vicinity of Miami.

In order to round out this account of the development of the reef corals and coral reefs in Florida and the southeastern United States as regards their relations to changing position of sea-level, the table on page 238 is taken from a paper by Vaughan.[2] As the stratigraphic relations of all the formations containing reef corals or coral reefs in the area mentioned have been studied, the conditions with reference to changing sea-level are known.

This table shows that all the important developments of reef corals in the area considered have taken place either during or subsequent to submergence. Vaughan's studies in the West Indies and on the Caribbean and Gulf shores of Central America have shown that the relations there are similar; and by combining data obtained by others in the Pacific area with the results of his own investigations, he has reached the conclusion that all important offshore reefs investigated have formed during or subsequent to submergence.

Because of the widespread interest in the subject, the bearing of the results obtained through the investigation of the coral reefs of Florida and the West Indies on coral-reef theory, especially the Darwin-Dana hypothesis, will be briefly stated. The hypothesis mentioned postulates not only subsidence but also a method of building platforms behind the reefs by a process of infilling and leveling. The reefs and platforms are supposed to grow upward simultaneously. As regards the relations to subsidence, or upward growth during or after submergence, the facts available are in accord with this hypothesis; but as regards the development of the marginal platforms they are not in accord.

[1]Compare these with Vaughan's statements on pp. 370–373.

[2]Abstr., Science, n. s., vol. 41, pp. 508–509, 1915; Bull. Geol. Sci. Amer., vol. 26, pp. 58–60, 1915.

The immediate foundation of the Tertiary coral reefs and coralliform beds of every horizon in the southeastern United States is known, except that of the living Florida barrier reef, through which no boring has been made, and the general geologic history of the Floridian Plateau is now familiar.[1] Without exception, the reef corals have merely grown upon an antecedent basement during or after subsidence and have played an unimportant rôle as constructional agents. There are six important submarine banks or groups of banks on the east side of Central and North America, as follows: Mosquito, Campeche, Florida, and Georges banks, those off Nova Scotia, and the Grand Banks of Newfoundland. They are all primarily of structural origin, and corals have had little or nothing to do with their formation; but corals have grown and still grow on the submerged surfaces of those which lie within the region where conditions are favorable for the life of such organisms.

Stratigraphic distribution of coral reefs and reef corals from Upper Oligocene to Recent time, and their relation to changing sea-level.

Series.	Geologic formations, members, and unconformities.	Distribution of reef corals and coral reefs.	Change in relation of basement to sea-level.
Recent	....	Coral reefs	Subsidence.
	Erosion unconformity.		
Pleistocene	....	Coral reefs	Subsidence.
	Erosion unconformity.		
Pliocene	Caloosahatchee	Reef corals	Subsidence.
	Erosion unconformity?		
Miocene	....	No reefs, but some corals	Subsidence.
	Erosion unconformity.		
Oligocene	Alum Bluff { Shoal River. Oak Grove. Chipola.	A few corals; slight development of reefs. A few corals, one species of reef coral	Continued subsidence.
	Chattahoochee { Upper. Lower.	Coral reefs (Tampa, Fla.). Coral reefs (Bainbridge, Ga.).	
	Erosion unconformity.		
Eocene	Ocala limestone	....	Subsidence.

Note on the Electrical State in Leaves, by J. C. Waller.

The grounds at Tortugas offer excellent opportunity for studying the electrical properties of leaves, under natural conditions, there being an abundant supply of a monocotyledonous plant, *Hymenocallis*, growing around the laboratory. The stiff leaves reach to a height of a meter or more, their bases broadening into colorless scales which together form a storage bulb. A plant transferred to a pot can, at will, be kept in darkness or exposed to the brilliant sunlight of the semitropics.

With the hope of making in the future a more exact study of the conditions which influence the electrical properties of plants, I made some observations on leaves, before and after exposure out of doors.

The apparatus used was that of my father, Dr. A. D. Waller, and was sent by him from England. He describes its use for the study of plants in "On blaze currents in vegetable tissues" (Linn. Soc. Bot., vol. XXXVII, pp. 32–50). In this paper he describes the electrical response to electrical excitation (which

[1]Vaughan, T. W., A contribution to the geologic history of the Floridian Plateau. Carnegie Inst. Wash. Pub. No. 133, pp. 99–185, 15 pls., 1910.

Matson, G. C., and S. Sanford, Geology and ground waters of Florida, U. S. Geol. Surv. Water Supply Paper 319, pp. 445, 17 pls., 1913.

he designates as the blaze current) and points out the variations of electrical conductivity in tissues at different stages of maturity and the great increase of conductivity which often takes place consequent to electrical stimulation; this increase, he surmises, is "partly due to the multiplication of electrolytes by dissociation."

Conductivity and Blaze Currents in Hymenocallis.

Series of observations made on leaves still attached to the plant show that the conductivity changes not only after electrical excitation, but that it varies at different times, owing to the action of natural conditions.

Further, in nearly all the cases observed by me, the blaze current (*i. e.*, electrical response to direct electrical excitation) is larger when the conductivity is low than when it is high. These changes may be realized by studying the table below, which gives the results of a typical experiment.

Leaf 60 cm. long; plant about to flower; electrodes 20 cm. from tip, 2 cm. apart, applied longitudinally in center of ventral surface. Electrical stimuli used, always of equal strength but fairly weak.

Time.	Temp.	Resistance calculated.	Blaze deflection.	Blaze calculated.
	°*C.*	*ohms.*	*cm.*	*volts.*
July 30, afternoon	29.5 to 30	1,184,000	Not taken.	.. .
July 31, after 21 hours in dark room	34	87,220	8	0 016
Evening, after half day's exposure to sun and rain	30 5	1,668,000	more than 60	more than 1 8

The above figures show that after 21 hours of darkness the conductivity has increased more than tenfold. After half a day's exposure to sun and rain the conductivity has again become low. On the other hand, the blaze response is vastly augmented after exposure.

It is possible that, expressed as volts, the last response is too high, a fallacy which might be produced, if there is a sudden increase of conductivity on initiation of the blaze-current. Leads at four other levels on this leaf gave similar variations of conductivity and response. The direction of the response may be the same as that of the stimulating current, or opposite, away from the leaf-base, or towards it.

Not all leaves gave such regular variations, nor did this leaf at a later stage; but I wish to repeat the experiments, avoiding disturbance to roots, gradual death of leaf, and other complicating factors.

Remarks.

My experiments indicate that light (rather than rain or temperature) has an influence on the subsequent electrical state of leaves. Dr. Waller's system of blaze currents (if I understand it) might offer some such explanation for the phenomena as the following:

Light—photosynthesis—condensation of electrolytes—decreased conductivity—storage of combustible material—increased power of response.

Dark—respiration predominant—increase of electrolytes—increase of conductivity—expenditure of combustible material—decreased power of response.

Perhaps it may be possible to test out some such hypothesis as this by means of chemical as well as electrical tests.

Dr. Shiro Tashiro and I have made experiments, using his delicate tests for carbon dioxide, in an attempt to obtain quantitative correlation between blaze response and the state of respiration. Practical difficulties, however, are considerable, and our results have not yet reached a stage for publication.—A. G. M.

Further Experiments Aiming at the Control of Defective and Monstrous Development, by E. I. Werber.

Starting from the hypothesis that the origin of monsters is due to parental metabolic toxæmia, experiments were carried out by the writer at the Marine Biological Laboratory at Woods Hole during the summer of 1914 on fertilized eggs of the marine teleost *Fundulus heteroclitus*, which were subjected at the early cleavage stages to the influence of solutions in sea-water of some substances found in the blood or urine respectively of man during certain disturbances of metabolism. With only two of these substances. *i. e.*, with butyric acid and acetone, definite and positive results have been obtained; a very great variety of monsters having been recorded,[1] which are strikingly analogous to the well-known monsters found in man and other mammals.

These experiments were continued and extended in the summer of 1915 with a view of testing the action of other toxic substances of pathologic metabolism on the teleost egg as well as of ascertaining, if possible, the mechanism of action of substances experiments with which have yielded the interesting results recorded in the work of the preceding year.

No definite data have as yet been obtained for the action of lactic acid, ammonium acetate, and ammonium benzoate, which have been employed in some experiments of this year. It seems unlikely, however, that any one of these substances might be responsible for defective development in nature; for solutions of them are practically harmless up to a certain degree, beyond which they are so highly toxic that eggs which are subjected to their action are killed at a very early stage of development--viz, before the formation of the embryo.

The repetition and extension of the successful experiments of 1914—*i. e.*, with butyric acid and acetone—afforded, however, a very good opportunity for studying the mechanism involved in the action of solutions of these substances in causing *Fundulus* eggs to develop in a monstrous manner. Thus it has so far been found that toxicity of the medium and increased permeability of the eggs' membrane which calls forth an increased imbibition of water are the principal factors leading to the formation of probably most of the monsters recorded in these investigations.

When the egg of *Fundulus* is subjected to the influence of butyric acid or acetone solutions its membrane is rendered more permeable than it is in its normal environment. On subsequent transfer to pure sea-water the eggs seem to imbibe more water than normally developing eggs, since a temporary increase in the volume of eggs transferred from these acid solutions to pure sea-water can be observed without difficulty. This rapid osmotic imbibition in turn causes a fragmentation of the germinal substance. Some parts of the latter may thus be entirely destroyed, owing to the increase in osmotic pressure, while the remainder may go on developing and eventually give rise to various monstrosities. This would account for the formation of meroplasts, recorded in these experiments in very great numbers, the most striking of which are the "solitary eye" and the "isolated eye," *i. e.*, eggs in which an eye develops from a small fragment of the medullary plate, an embryo being either entirely absent or, if present, being in no connection whatsoever with the eye, which has developed independently at a great distance from it. Of these cases of independent development of the eye a relatively great number have occurred in this summer's experiments.

To blastolytic action caused by an increase in the osmotic pressure of the environment are evidently due also other cases of malformation, such as

[1]Werber, E. I., Experimental studies aiming at the control of defective and monstrous development. A survey of recorded monstrosities, with special attention to the ophthalmic defects. Anat. Record, vol. 9, No. 7, 1915.

various duplicities (quite a number of which were recorded this summer), amorphous embryos, and other general deformities.

However, besides the increase in osmotic pressure, there is another factor, viz, toxicity of the medium, which is responsible for blastolysis. The solutions of the organic acids employed in these experiments seem to have a solvent effect on the egg. When the eggs are transferred from these solutions to pure sea-water they swell at first and then some dissolved parts of their substance are seen to pass out of them into the water. This can be observed in a striking manner, particularly in eggs which have been treated with butyric acid. In some of them, which eventually give rise to extremely deformed embryos, the yolk-sacs are reduced to a very small size, owing to this loss of substance.

The substances which pass out of the egg after transfer to pure sea-water form a sediment on the bottom of the dish, which is slimy in butyric-acid experiments and of a granular consistency in acetone experiments. It is planned to collect these sediments during the next season, and by means of chemical analysis to thus ascertain the chemical effects which these acids produce on the egg.

There are, then, two processes involved in the blastolytic action. For the sake of convenience I shall term the supposedly solvent action of the substances employed—which manifests itself in the destruction of a certain area—the toxic blastolysis, while the fragmentation due to osmotic pressure will be referred to as osmotic blastolysis.

In most monsters which are produced by the influence of butyric acid and acetone solutions both factors play an important part, the toxic blastolysis being followed on transfer to pure sea-water by osmotic blastolysis. In embryos, however, whose defects are mainly restricted to the eyes, the effect is largely due to toxic blastolysis, for there is in such cases usually only a slight indication of dissociation by osmotic pressure.

Similar effects can also be produced by lowering the temperature of the eggs' environment. Loeb[1] has recently shown that if *Fundulus* eggs be kept on ice for certain periods of their development some of them will develop into monsters. I have repeated these experiments this summer and have obtained the same results, even with a much higher temperature than the one used by Loeb. However, in this case, too, I was able to observe escape of substance from the egg, which resulted in a striking reduction of the volume of the yolk in eggs which had developed in a monstrous manner. This escape of substance seems largely due to shrinkage caused by the low temperature. Thus some monsters produced by the effect of low temperature on the developing egg may be due to loss of the egg's substance, while the ophthalmic monsters are probably due mainly to the injurious effects of the lower temperature. As I have pointed out elsewhere, the ophthalmic defects in my chemical experiments seem to be due to toxic blastolysis, by which the potential ophthalmoblastic material is primarily affected. This part of the egg is evidently characterized by a high degree of sensitivity, and is most rapidly altered in the chemical experiment as well as in the temperature experiment.

The rudimentary development of the blood vascular system in eggs so treated is, contrary to Loeb's assumption, in no causal connection with the ophthalmic defects. It is well known that in the normal development the optic vesicles are laid down long before any blood-vessels are formed.

[1]Loeb, J., The blindness of the cave fauna and the artificial production of blind fish embryos by heterogeneous hybridization and by low temperatures. Biol. Bulletin, vol. XXIX, No. 1, 1915.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

BENJAMIN BOSS, DIRECTOR.

STELLAR MOTIONS.

Most of the methods of dealing with preferential motion fail when applied to the B-type stars on account of their small peculiar motions, together with their small average parallax, their peculiar distribution in a belt almost coincident with the galaxy, and their uneven distribution along this belt.

Since the close agreement of the apex of solar motion as derived from the proper-motions of the B-type stars, with the apex derived from all types combined, indicates that the motions of the B-type stars are symmetrical with respect to the general system, a simple method has been employed for the determination of any existing preference of motion among them.

The B-type stars of the Preliminary General Catalogue have been grouped in areas according to their natural grouping in the sky, and a center of motion has been determined from the actual proper-motions. The position-angles and amount of proper-motion from this center were graphically represented by smooth curves whose abscissæ represent position-angle and whose ordinates represent amount of proper-motion. The curves thus determined were mostly very smooth, with definite maxima, each maximum indicating the existence of preferential motion.

When the paths leading from the center of the areas in the direction of the preferences of motion were plotted, it became apparent that with one exception each area contained a clearly marked preference for motion in the plane of the B-type stars, a plane slightly inclined to the path of the galaxy. In addition, many of the curves indicated a second maximum, showing the existence of a strong tendency for a portion of the B-type stars to leave their own plane. There was nothing of a systematic character in this tendency. Thus the investigation shows that while the motions of a large proportion of the B-type stars will preserve their present plane, contrary to existing notions, the scattering of the stars, which becomes so apparent in later types, has a well-marked beginning in the B-type stage.

The same method will subsequently be applied to stars of later types.

Mr. Raymond is at present working on the determination of preferential motion of the stars by a new method, devised by him several years ago. This method takes account of the amounts as well as of the direction of the proper-motions; it is a modification of that used by Newcomb in his paper "On the position of the Galactic and other principal planes toward which the stars tend to crowd" (Carnegie Inst.

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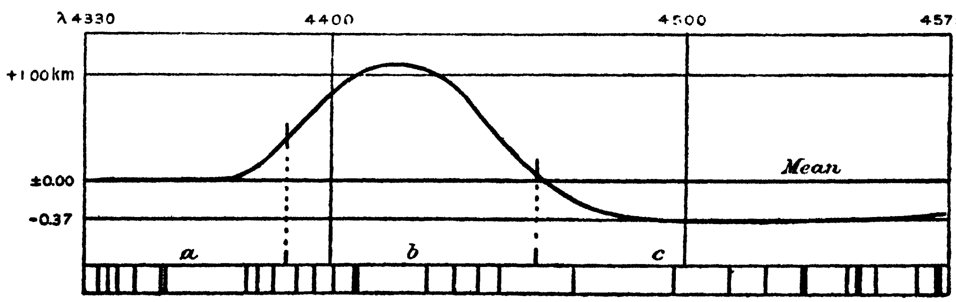
Wash. Pub. No. 10). While the theoretical part, as already stated, has been prepared for some time, the practical application and computation were not started until recently. As the computations are only half completed no results can be incorporated in the present report.

Dr. Albrecht is preparing an article on "A method for rendering stellar radial velocities homogeneous within each spectral type." It is to a limited extent known that perfect homogeneity does not exist in stellar radial velocity results, even when we confine ourselves to stars of one spectral type and to one spectrograph. However, no remedy for this unsatisfactory state of affairs has been suggested. Though the more general problem is quite complex, the greater immediate need and prerequisite is to place the radial velocities within each stellar type upon a well-defined and uniform basis. The restricted problem yields to a very simple and effective solution.

The values of the radial velocity given by the individual lines are plotted with velocities as ordinates and wave-lengths as abscissæ, and a smooth curve is drawn through the plotted points. In actual practice it is found that this curve deviates quite appreciably from the horizontal straight line which represents the mean of all the lines, *i. e.*, the radial velocity for the spectrogram, and these deviations measure the extent to which an internal non-homogeneity exists in the reduction of this spectrogram. This internal non-homogeneity—the causes for which need not be dwelt upon here—together with a non-uniformity in intensity which makes it impossible in practice to always employ the same identical list of lines on all plates of any one star or of all stars of one spectral class, constitutes the principal factor which introduces the non-homogeneity considered in this article.



9 lines in *b* give Mean +0.74 km. 13 lines in *c* give Mean −0.37 km.

FIG. 2.—Composite of Individual Curves.

In order to eliminate from the above curve deviations of an accidental nature, the same process is repeated for a representative number of spectrograms and a curve is constructed which is a composite of all the individual curves. Such a composite curve is reproduced in the figure. It is evident that the three sections into which this curve has been arbitrarily divided yield radial velocities differing quite appreciably from each other and from the mean.

The illustration above is taken from regular radial-velocity work with three prisms, and may be considered representative. The remedy, both effective and simple, is an arbitrary adjustment of the wave-lengths (separately for each spectral class) so that in the mean for a large number of plates every line or group of lines will yield the same radial velocity as every other line or group of lines. This adjustment would bring the composite curve in the figure into coincidence with the horizontal straight line representing the mean. Nor is this procedure in reality more arbitrary, except for class G, than the present methods for adopting the wave-lengths to represent zero radial velocity in each spectral class.

Perhaps the most serious consequence of the neglect of this adjustment is the practically invariable introduction of systematic difference between the brighter and the fainter stars. It is the experience of observers that on spectrograms of the fainter stars the portion toward the violet is very much underexposed, so that only about the half of the plate toward the longer wave-lengths is available for measurement. Thus, whatever systematic difference may exist between the entire spectrogram and the half toward the longer wave-lengths will also appear, with nearly full effect, as a systematic difference between the brighter and the fainter stars. The great advantage gained from the adjustment is that the radial velocities from all spectrograms of any one star or of any one spectral class will be on a uniform basis, which basis can be accurately defined, and can thus be employed with confidence in various statistical investigations.

Dr. Albrecht has published an article on "Anomalous dispersion in the Sun" (Astrophysical Journal, volume XLI, No. 5, June 1915), a summary of which is given. According to the theory of anomalous dispersion as developed by Julius, Fraunhofer lines which are separated from each other by only very short distances (about 0.5 A or less) should produce mutual displacements of the lines, the violet and red components of a pair being displaced in opposite directions, the former somewhat more than the latter. Rowland's "Preliminary table of solar spectrum wave-lengths" forms a suitable basis with which to make a test for this effect. In the test made (which is necessarily preliminary), the Fe lines alone were employed, the chief reasons for thus restricting the data being the following: (*a*) for these lines well-determined laboratory wave-lengths are available for the necessary comparisons; (*b*) as spectrum lines are affected selectively by pressure and as it is desirable to eliminate the unequal pressure effects, the data were further restricted to those Fe lines which had been classified according to pressure-shifts.

The principal results derived are: Lines with close companions toward the red in the solar spectrum are shifted toward the violet, and line with close companions toward the violet are shifted toward the red.

The displacement varies in amount with the separation of the lines, though for all separations it is greater when the companion line is toward the red than when it is toward the violet of the line. This is well illustrated in table A. The subscripts indicate the number of lines included in each mean. For a mean separation of 0.22 A the displacements are respectively 0.007 A and 0.005 A. These facts are in accord with the requirements of the theory of Julius, and they seem definitely to establish the operation of anomalous dispersion in the sun.

TABLE A.—*Means—Displacement according to separation from companion.*

Lines with—	Separation.		
	0.0 to 0.2 A.	0.2 to 0.4 A.	0.4 A and greater.
Companion toward the red.......	$+.0103_{11}$	$+.0065_{17}$	$+.0036_{10}$
Companion toward the violet......	$-.0073_{24}$	$-.0024_{31}$	$-.0010_{9}$

Additional results and conclusions are:

(1) A method is developed by which Rowland's Preliminary Table of Solar Spectrum Wave-lengths is made available for comparison of solar wave-lengths with the best recent laboratory wave-lengths.

(2) The Mount Wilson classification of spectrum lines according to behavior under pressure is confirmed.

(3) It was shown that the pressure in the solar reversing layer where the Fe Fraunhofer lines originate is 0.5 atmosphere.

(4) As a direct consequence of the progressive variation in intensity of lines in stellar spectra—some lines gradually disappearing and new lines coming in and increasing in strength as we proceed from type to type, thereby causing neighboring lines to change very markedly in relative intensity, some lines gradually losing companions while others gain them—anomalous dispersion becomes *one* of the causes producing the changes of wave-length which are progressive with the stellar spectral type.

(5) The comparison of the arc wave-lengths of Burns and of Mount Wilson and Pasadena (both of which are of high quality) revealed the necessity of stipulating more definite standard conditions in laboratory determinations of wave-length, including standards of wave-length.

The Director, with Dr. von Flotow, has investigated the parallaxes of the large proper-motion stars on the hypothesis of parallelism of motion toward the apices of preferential motion. In so far as these large proper-motions represent large real velocities of the stars, the hypothetical parallaxes should be very fair approximations to the truth, for according to the well-established fact of preferential motion the larger motions should be found in the direction of the apices of preferential motion. But the large apparent motions of a considerable number of the large proper-motion stars are due to their

proximity to us. These stars do not necessarily move in any chosen direction and consequently can not be expected to yield accordant hypothetical parallaxes. Two methods were employed, one involving distance and position-angle from the assumed vertex of preferential motion, and the other involving position-angle alone. The latter method proved more satisfactory. A comparison with observed parallaxes indicated that the mean value of the hypothetical parallax was too great.

As might be expected, there are considerable discrepancies between observed and hypothetical parallaxes for individual stars, though it is noticeable that the agreement between computed and observed values are more in accordance in the case of parallaxes determined by heliometer observations than in the case of meridian observations. The negative parallaxes amount to 9 per cent of the whole number. There are also some abnormally large values of the computed parallax, the great majority occurring where the observed parallax amounts to more than 0″.1. Barring the abnormal cases, there is very fair agreement between the means of the observed and hypothetical parallaxes for cases where the observed parallax amounts to more than 0″.1. For smaller parallaxes the means of the computed are very much larger than the means of the observed.

As a preliminary to discussing the proper-motions of the zone catalogue the solar motion has been deduced, placing the apex of the sun's way at R. A. = 277°.0, Decl. = +35°.4. Considering the restricted distribution of the material this result is surprisingly good.

OBSERVATIONS.

During the year 20,219 observations were taken on 137 nights. The observations were distributed among the observers as follows: S. Albrecht, 4,628; A. J. Roy, 11,157; W. B. Varnum, 4,434. The circle-readings for zenith distance showed the following distribution: S. B. Grant, 6,236; H. Jenkins, 4,967; H. Raymond, 8,960. In respect to the four positions of the instrument these observations were distributed—AE 3,318, AW 2,646, BE 6,242, BW 8,013. As large portions of the summer observing list have been completed for miscellaneous stars, the last few months have been mainly employed in an attempt to strengthen the fundamental program, but with little success, since the almost continuous rainy and cloudy weather has broken the continuity of the series.

REDUCTION OF OBSERVATIONS.

The preliminary steps in the reduction of the current observations have been kept nearly up to date. The means of the transits have been taken and the transits reduced to the mean wire. The accumulating material persists in showing the personality among the various observers with respect to difference in wire-interval.

The means of microscope readings have been computed and the corrections for division error and error of runs applied. The corrected zenith distances have been transcribed to the computation sheets, and the corrections for inclination of the zenith distance wire, curvature, and the combined telescope and circle flexure have already been applied. The inclination has been determined by scattered observations extending over three and one-half years. The adopted value is 0″.987 per 10^s of equatorial time, with a probable error of ±0″.009. As few bisections are ever made at a distance greater than 20^s from the central wire, this is the most precise of the instrumental corrections.

Computation of apparent place reductions is but little in arrears and the computation of refractions is well under way.

Further material has been gathered for the determination of the causes underlying the changes in collimation. This material lends confirmation to the conclusion derived from an investigation by Mr. Roy which indicates an effect similar to lost motion over a temperature range of approximately 22° C.

The critical examination of the San Luis microscope readings has been completed, uncovering 922 errors of various kinds in the more than 350,000 readings. About a third of the errors were found in the computation of means and the application of division correction, but the rest were errors of 5 or 10 seconds, and others of a miscellaneous nature. The proportion of these errors which might otherwise have escaped detection is sufficiently large to warrant a similar examination of the microscope readings of the Albany observations.

The completion of the examination of the San Luis circle readings marked the forward movement in the reduction of the zenith distances. A first approximation to a system for the reduction of the observations has been made. With the Preliminary General Catalogue as a basis, systematic corrections have been derived to reconcile it with the San Luis results. Mr. Roy finds that not only do the three fundamental observers differ from one another in the four positions of the instrument, but that there are decided systematic differences in the results obtained by each individual in the four positions of the instrument. The low altitude of the pole prevented a thoroughly independent determination of refraction constants, but in order to allow to some extent for corrections of this nature a tangent term was introduced.

Table B.—*Preliminary corrections to P. G. C.*

−90°	0″.00	−40°	+0″.28	+10°	+0″.07
85	0.00	−35	+0.23	15	+0.09
80	0.00	−30	+0.18	20	+0.11
75	0.00	−25	+0.13	25	+0.13
70	0.00	−20	+0.09	30	+0.15
−65	0.00	−15	+0.05	+35	+0.18
60	+0.18	−10	+0.01	40	+0.20
55	+0.38	− 5	+0.01	45	+0.24
50	+0.40	0	+0.01	+50	+0.27
45	+0.37	+ 5	+0.04		

The application of the systematic corrections to latitude and of the tangent term leaves the residuals which form table B. While the curve drawn to represent the observed corrections to the Preliminary General Catalogue is on the whole very smooth, there is an abrupt break at about $-60°$. No explanation has developed to account for this sudden break.

The duplicate copies of the reductions of the San Luis observations in right ascension have been reconciled, and the observations of the fundamental stars drawn off for discussion.

Mr. Varnum separated the observations of each star according as they were taken with the instrument in the position clamp east or clamp west. The mean position in each clamp was then compared with the place given in the Preliminary General Catalogue. The residuals thus formed were drawn off in the order of the declination of the stars, and means were taken for each degree. These means from clamp east and clamp west indicate the correction to the Preliminary General Catalogue to reduce it to the system of the San Luis observations and should yield similar results; but, when plotted, a very anomalous region appeared, so striking as to make it evident that the observations must require an additional correction for pivot.

As a preliminary to determining the outstanding pivot factor, the residuals were freed approximately from the effect of error dependent on declination, by means of a curve which represented the mean of clamp east and clamp west. The outstanding residuals were then treated as dependent upon uncorrected inequality and irregularity of pivots. The inequality of pivots introduces errors in the collimation, the level, and the azimuth. These assume the form of

$$C+a \sin R+b \cos R$$

where R refers to the circle-reading on the same circle both clamp east and clamp west. The equation was solved from the data by least squares and then was applied to the residuals.

This left a well-defined periodic term due to irregularity of pivots, and represented by the formula

$$c \sin 6R+d \cos 6R$$

It was found, however, that the agreement between observed and computed values did not extend beyond $R=318°$. Therefore a separate solution was made for the region from $R=318°$ to $278°$.

By successive approximations the following formulas were deduced as representing outstanding pivot correction:

For clamp east from declination $+8\overset{\circ}{.}7$ to $-64°$ S. P.:

$$+\overset{s}{.}0176+\overset{s}{.}0063 \sin R-\overset{s}{.}0296 \cos R-\overset{s}{.}0028 \sin 6R-\overset{s}{.}0084 \cos 6R$$

For clamp east from declination $+8\overset{\circ}{.}7$ to $+50°$:

$$+\overset{s}{.}0176+\overset{s}{.}0063 \sin R-\overset{s}{.}0296 \cos R+\overset{s}{.}0078 \sin 6R+\overset{s}{.}0071 \cos 6R$$

Table C gives the numerical results. Column 1 refers to the mean circle-reading of the stars employed in each group; column 2 is the residual uncorrected for effect of pivot and reduced to equatorial

TABLE C.

Circle reading.	$\frac{E-W}{2}$	First correction.	$\frac{E-W}{2}$ corrected.	Second correction.	$O-C$.	Weights.
79.6	−.0295	+.0184	−.0111	+.0014	−.0097	1
76.5	−.0155	+.0168	+.0013	−.0014	−.0001	2
73.8	−.0100	+.0159	+.0059	−.0038	+.0021	2
71.1	−.0110	+.0140	+.0030	−.0059	−.0029	2
67.6	− 0080	+.0121	+.0041	−.0078	−.0037	2
64.9	−.0050	+ 0107	+.0057	−.0087	−.0030	2
61.5	+.0060	+.0090	+.0150	−.0088	+.0062	2
58.5	+.0010	+.0075	+.0085	−.0078	+.0007	2
55 3	.0000	+ 0060	+.0060	−.0061	−.0001	1
52.4	− 0045	+.0045	.0000	−.0039	−.0039	2
49.5	−.0005	+.0032	+.0027	−.0013	+.0014	2
46.4	−.0030	+.0018	−.0012	+.0016	+.0004	3
43.8	−.0125	+.0006	−.0119	+.0038	−.0081	3
40.6	−.0100	−.0008	−.0108	+.0062	−.0046	2
37.5	− 0085	− 0021	−.0106	+.0079	−.0027	3
34.6	−.0045	−.0032	−.0077	+.0087	+.0010	3
31.7	−.0035	−.0043	−.0078	+.0088	+.0010	3
28.6	−.0020	− 0053	−.0073	+.0079	+.0006	3
25.2	− 0035	−.0065	−.0100	+.0060	−.0040	3
22.6	+.0025	− 0073	−.0048	+.0041	− 0007	2
19.1	+.0070	−.0083	−.0013	+.0010	−.0003	3
16 6	+.0130	−.0090	+.0040	−.0014	+.0026	2
13.5	+.0105	−.0097	+.0008	−.0041	−.0033	3
10.3	+.0170	−.0104	+.0066	−.0064	+.0002	4
7.5	+.0210	−.0109	+.0101	−.0079	+.0022	5
4.5	+.0200	−.0114	+.0086	−.0087	−.0001	7
1.4	+.0210	−.0118	+.0092	−.0087	+.0005	5
358 6	+.0215	−.0122	+.0093	−.0079	+.0014	5
355.5	+.0200	−.0124	+.0076	−.0062	+.0014	7
352.5	+.0165	−.0125	+.0040	−.0040	.0000	5
349.8	+.0175	−.0126	+.0049	−.0016	+.0033	4
346.5	+.0155	−.0127	+.0028	+.0015	+.0043	3
343.4	+.0075	−.0126	−.0051	+.0041	−.0010	2
340.7	+.0125	−.0124	+.0001	+.0061	+.0062	3
337.4	+.0075	−.0121	−.0046	+.0079	+.0033	2
334.7	+.0090	−.0119	− 0029	+.0087	+.0058	3
331.4	+.0030	−.0114	− 0084	+.0087	+.0003	3
328.2	+.0040	−.0109	− 0069	+.0077	+.0008	3
325.2	+.0030	−.0103	−.0073	+.0060	−.0013	3
322.5	+.0085	− 0097	−.0012	+.0040	+.0028	3
319.5	+.0125	−.0090	+.0035	+.0009	+.0044	2
316.3	+ 0100	−.0082	+.0018	+.0048	+ 0066	2
313.6	+.0005	−.0074	−.0069	+.0068	−.0001	3
310.5	−.0005	−.0064	−.0069	+.0081	+.0012	2
307.6	+.0035	−.0055	−.0020	+.0085	+.0065	2
304.7	−.0070	−.0044	−.0114	+.0080	−.0034	1
301.5	−.0045	−.0033	−.0078	+.0063	−.0015	2
298.5	−.0090	−.0020	−.0110	+.0037	−.0073	2
295.0	+.0025	−.0006	+.0019	+.0002	+.0021	2
292.4	−.0030	+.0005	−.0025	−.0026	−.0051	2
289.1	+.0135	+.0019	+.0154	−.0061	+.0093	1
286.3	+.0115	+.0033	+.0148	−.0088	+.0060	2
283.6	+.0050	+.0045	+.0095	−.0108	−.0013	2
280.4	+.0220	+.0060	+.0280	−.0122	+.0158	1

interval; column 3 evaluates the formula $+ {}^s\!.0176 + {}^s\!.0063 \sin R - {}^s\!.0296 \cos R$; column 4 is the resulting corrected residual; column 5 shows the corrections derived from the formula $- {}^s\!.0028 \sin 6R - {}^s\!.0084 \cos 6R$ for $R = 82°$ to $318°$, and the formula $+ {}^s\!.0078 \sin 6R + {}^s\!.0071 \cos 6R$ for $R = 318°$ to $278°$; column 6 is the residual left after application of the second correction. It indicates a probable error of $\pm {}^s\!.0036 \sec \delta$, or, omitting the last residual, $\pm {}^s\!.0027 \sec \delta$; column 7 represents the weights employed in the least-square solutions, based on the number of observations contained in each grouping.

A comparison between the pivot corrections employed in reducing the San Luis observations and the newly determined values shows them to be of the same form, but the curves representing the old values did not reach quite high enough nor dip quite low enough to satisfy the observed maxima and minima.

STAFF.

In addition to his regular duties, the Director has been engaged upon various problems in stellar motion. Mr. A. J. Roy has remained in charge of the observations and has supervised the reduction of observations, being especially employed on the zenith distances of the San Luis observations. Mr. W. B. Varnum, besides his duties as observer, has reconciled the reductions of the San Luis right ascensions and has discussed the observed places for outstanding instrumental corrections, which resulted in a modification of the pivot correction. He is now prepared to form the final places. Dr. S. Albrecht has divided his time between observing, reducing observations, and continuing his studies on standards of wave-length. Mr. H. Raymond is employed upon a new method of determining the velocity figure of the distribution of stellar motions; he has also been engaged in various phases of the reduction of observations and has read circles. Mr. H. Jenkins continues as circle-reader and in addition is employed upon the computations. Mr. S. B. Grant has undertaken similar duties. Prof. Dr. A. von Flotow joined the staff late in January 1915; he has been aiding the Director in an attempt to determine the hypothetical parallaxes of the large proper-motion stars. In the regular computing division able assistance has been rendered by Mary E. Bingham, Grace I. Buffum, Livia C. Clark, Mabel A. Dyer, Alice M. Fuller, Florence L. Gale, Bertha W. Jones, Isabella Lange, and Frances L. MacNeill. Four piece-work computers have also been employed.

MOUNT WILSON SOLAR OBSERVATORY.*

George E. Hale, Director.

The progress of the year, in spite of unusually cloudy weather in the winter and spring, has been satisfactory in all departments of the Observatory's work. The reconstructed 60-foot tower telescope, for which a spectroheliograph of 13 feet focal length has been built, has proved of great service in the enlarged scheme of solar observations. The 60-inch reflector still remains our only instrument for work on stars and nebulæ, but the 10-inch portrait-lens telescope is now nearly ready for use, and the completion of the larger parts of the 100-inch reflector mounting makes it probable that this instrument will be in working order by the end of 1916. As the laboratory equipment has also been increased, by the addition of apparatus for the study of the Stark effect, the entire general plan of research, which has been gradually taking form since the inception of the Observatory, will soon be completed and in operation. A series of investigations on nebulæ, which will form a part of this plan, has recently been outlined with the valued counsel of Professor Chamberlin.

STAFF.

The Director has continued his investigations of solar phenomena and has conducted a series of vortex experiments with the assistance of Mr. Luckey. Dr. Walter S. Adams has carried on his work as Assistant Director and head of the department of stellar spectroscopy, together with a variety of researches on stellar and solar spectra. Professor Frederick H. Seares, superintendent of the Computing Division and editor of the Observatory publications, has continued his investigations in stellar photometry and his work on the position of the magnetic axis of the sun. Dr. Arthur S. King, superintendent of the Physical Laboratory, has been engaged mainly in the study of furnace and spark spectra. Professor G. W. Ritchey, who discontinued his astronomical observations in 1911 in order to have time for private business as an optician, has returned to the photography of nebulæ, besides continuing his work on the 100-inch mirror. Dr. Charles E. St. John has carried forward his solar investigations and his studies of the electric arc. Mr. Harold D. Babcock has studied the pole effect in the arc jointly with Dr. St. John, continued his work on the Zeeman effect, and experimented with the interferometer for the investigation of nebulæ. Mr. Ferdinand Ellerman has performed his usual duties as Observatory photographer and continued his work with the Snow and tower telescopes. Mr. Francis G. Pease has gone on

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with his photographic work on nebulæ and their spectra and on the spectra of star clusters and Novæ. Dr. Arnold Kohlschütter, who was captured by the British while on his way to join the German army, is held in England as a prisoner of war. Dr. Harlow Shapley, in addition to other work in stellar photometry, has made an extensive study of the colors and magnitudes of stars in Messier 13. Dr. Adriaan van Maanen has devoted all of his observing time to work on stellar parallaxes and has continued his measurements of spectra showing the general magnetic field of the sun. Dr. Walter Colby, who came from the University of Michigan in October to spend a year at the Observatory, has shared in the solar observations with the Snow and tower telescopes and in the work with the Koch microphotometer. Mr. R. S. Capon, of Oxford, who had been engaged in various kinds of solar work, returned to England in December and is now serving in the army. Mr. George P. Luckey, who began work at the Observatory in February, has assisted in the solar and stellar spectroscopic observations and devoted much time to vortex experiments. Mr. George S. Monk has taken part in the solar and stellar spectroscopic observations and in the work with the microphotometer.

Professor J. C. Kapteyn has continued his investigations as Research Associate. In anticipation of remaining in Holland this summer, he doubled the time of his stay on Mount Wilson last year, and hopes to return as usual in June 1916. Professor Carl Störmer, who has completed for publication his investigation of the electromagnetic theory of the hydrogen flocculi, has been reappointed as Research Associate. Professor T. C. Chamberlin, of the University of Chicago, who has long been a Research Associate of the Carnegie Institution of Washington, spent two months on Mount Wilson during the summer of 1915. During this time he prepared for us an extended paper on a "Tentative Interpretation of Nebulæ," which will be published in the *Contributions*.

Director C. G. Abbot, of the Smithsonian Astrophysical Observatory, has continued his work on Mount Wilson during the summer of 1915 with the assistance of Mr. L. B. Aldrich.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

DIFFERENTIAL METHODS OF MEASUREMENT.

The recent rise into significance of the fourth decimal place in wave-length measurements of spectrum lines is one of the most important developments of modern spectroscopy While it promises a long series of discoveries in the future, it greatly complicates the work of the present. In the electric arc, as the investigations of Mr. St. John and Mr. Babcock have recently shown (see p. 278), displacements of several thousandths of an angstrom occur for many lines in passing from the center to the pole. Such shifts, which exhibit large variations

for different groups of lines, must be measured and eliminated, and their effect on pressure displacements and other spectroscopic phenomena must be determined. Only after the completion of much work of this kind can we advantageously resume the task of interpreting the displacements of the Fraunhofer lines at the center and limb of the sun.

But the increased refinement now demanded is not limited to a knowledge of line displacements in the arc and other sources; indeed, these very shifts can not be determined with sufficient accuracy by existing methods. Mr. St. John and Mr. Babcock have materially reduced the errors arising in the comparison of lines from two sources by making both the exposures simultaneously, but the difficulty remains of securing precisely similar illumination of the grating in both cases. Doubtless this inequality of illumination is one of the causes of the surprising discrepancy between the results of different determinations of the solar rotation. Mr. Adams's conclusion that the rotational velocity is a function of the level in the solar atmosphere, though fully supported by the measures of Mr. St. John and Miss Ware, and apparently placed beyond doubt by recent work with the Koch microphotometer (see p. 262), has not been confirmed by other observers in England, Canada, and the United States. The detection of differences in velocity for lines of different intensity probably depends mainly upon the linear dispersion of the spectrograph and the diameter of the solar image employed, but errors in the absolute velocity are likely to arise from imperfect illumination of the grating. In any case, the use of a purely differential method, involving only a single exposure and the illumination of the grating from a single source, is highly desirable in all of the investigations mentioned.

In the study of the general magnetic field of the sun, displacements of solar lines as small as 0.0001 A can be measured with the aid of a compound quarter-wave plate, mounted above a Nicol prism over the slit of the spectrograph. The photograph of the spectrum is divided into narrow strips (1 or 2 mm. wide) corresponding to the successive strips of the quarter-wave plate, the principal sections of which make angles of $+45°$ and $-45°$ with the axis of the nicol. Thus the elliptically polarized edges of the lines affected by the field are cut off, in the odd strips on the violet side, in the even strips on the red side. The resulting displacements of the lines in adjoining strips are measured with a parallel plate micrometer, in which the lines are brought into coincidence by inclining a narrow glass plate through which a single strip is seen.

The advantage of this device is that the spectra to be compared are obtained in a single exposure, with the same illumination of the grating. The superposition upon the solar or arc spectrum of an iodine absorption spectrum for comparison purposes would accomplish a similar result (for some regions), were it not for the multiplicity of the iodine

lines, which fall upon the solar lines and interfere with their measurement. An attempt will therefore be made to imitate closely the results obtained with the compound quarter-wave plate by constructing a compound iodine-vapor cell, with absorbing chambers 1 or 2 mm. wide, separated by vacuum cells of the same width. If this simple device is successful, the iodine lines superposed upon the solar spectrum will appear on the odd strips, while the solar spectrum will appear alone on the even strips. Whatever be the outcome of this experiment, it seems certain that some such differential method, requiring only a single illumination of the grating, will be necessary to meet the present rigorous demands for increased accuracy of measurement in solar and laboratory spectroscopy. For the elimination of personal equation, a problem of great importance, the Koch microphotometer seems to be entirely satisfactory, and it is to be hoped that it will come into more general use.

But spectroscopic measurements are not the only ones in which increased accuracy is needed. In work with the spectroheliograph it is often desirable to determine small displacements of flocculi not measurable by existing methods, because of local distortions due to drift of the image during the exposure, temporary poor seeing, changing refraction during long exposures with low sun, and other causes. The 13-foot spectroheliograph recently built for the 60-foot tower telescope is accordingly provided with two camera slits, one of which may be set on $H\alpha$ (or any desired line), while the other, at a distance of several inches, is set on the continuous spectrum. Thus two images of the same region of the sun may be photographed simultaneously on a single plate, one showing the flocculi surrounding a group of sun-spots, the other the spots themselves. Fine wires stretched across the collimator slit together with the images of the two camera slits at the end of the run furnish the necessary fiducial lines, with reference to which the positions of spots and flocculi can be measured. Thus the motions of flocculi can be determined differentially with reference to sun-spots on solar images affected in precisely the same degree by any source of distortion.

INSTRUMENTS.

The completion of the remodeled 60-foot tower telescope and its auxiliaries, which include a spectroheliograph of 13 feet focal length, has greatly strengthened the equipment available for solar research. The improved 30-foot spectrograph, which can now be easily transformed into an 18-foot spectrograph for use with a quartz invar interferometer, has been provided with vacuum and mercury arcs, a device for exposing simultaneously on arc and solar image, and other new accessories. The 13-foot spectroheliograph has proved to be very satisfactory. The frame of angle iron which supports the optical parts is suspended in the underground chamber from a heavy carriage

resting on four steel balls, and moved as a whole by an electric motor. Thus the solar image and photographic plate are stationary, while the collimator and camera slits move with the spectroheliograph across them. The 4-inch plane grating used in this instrument, which is extremely bright in the first order, was ruled by Anderson. As the axes of the collimator and camera lenses are parallel, the beam, after leaving the grating, falls on a plane mirror, from which it is reflected through the camera lens. This mirror may be moved along the axis of the camera lens, thus making it possible to change the angle between the incident and diffracted beams and hence to vary the linear dispersion of the first-order spectrum.

The two-slit device giving images of sun-spots and flocculi simultaneously on a single plate for differential measurement has been mentioned above (p. 254). By providing two gratings or two mirrors below the camera lens, two images of the spectrum from a single collimator slit can be produced side by side. Thus by setting one camera slit on the red edge of $H\alpha$ in one spectrum and a second camera slit on the violet edge of $H\alpha$ in the other spectrum, photographs of flocculi can be obtained with the two edges simultaneously. Similarly two or even three photographs, showing sections of the flocculi at as many different levels, can also be taken simultaneously.

Other improvements in solar instruments include an arrangement by which a single prism, for photography with K_2, can be quickly substituted in the 5-foot spectroheliograph for the two prisms used with $H\alpha$; a new set of electric hand controls and cables for the quick and slow motions of the 75-foot spectrograph and 150-foot tower telescope; and a new quadruplex electric pump for the water-circulating system of the cœlostat mirrors of the latter instrument, which eliminates the vibration produced by the old pump.

SOLAR PHOTOGRAPHY.

During the year, 284 direct photographs of the sun have been taken with the Snow telescope, and the daily work with the 5-foot spectroheliograph has been continued by Messrs. Ellerman, Colby, Monk, Capon, Luckey, and Campbell. Of the total number of 1,072 negatives secured, 507 are $H\alpha$ disk plates, 293 are K_2 disk plates, and 272 are K_2 prominence plates. When interesting flocculi were present, series of successive exposures were also made with $H\alpha$.

The 13-foot spectroheliograph of the 60-foot tower telescope was installed in July and first used on July 25. Since that date 225 negatives of interesting flocculi and prominences, each containing from 1 to 12 exposures, have been obtained with it by Messrs. Ellerman, Colby, Monk, and Luckey. These include daily photographs (since August 3) of a 2-inch solar image with the center of $H\alpha$ and series of photographs of interesting regions of a 6.5-inch solar image. Special

attention has been given to comparative photographs of prominences in $H\alpha$ and K light, comparative photographs of hydrogen flocculi with the center and the red and violet edges of $H\alpha$, and series of photographs of the $H\alpha$ flocculi surrounding bipolar spot-groups, in connection with laboratory investigations of vortex phenomena.

FIELDS OF FORCE IN THE SOLAR ATMOSPHERE.

The typical hydrogen flocculi connected with sun-spots may be classified under three heads: (1) unipolar flocculi, consisting of curved or radial lines surrounding single spots; (2) bipolar flocculi, surrounding a bipolar spot group, and resembling imperfectly the lines of force about a bar magnet; and (3) multipolar flocculi, more or less similar to bipolar flocculi, but influenced in form by the presence of numerous small spots, of either polarity, in a complex spot group. The fields of force thus made manifest in the solar atmosphere have been explained by some investigators as hydrodynamic phenomena, while others have attributed them to the influence of the magnetic fields in sun-spots on falling hydrogen ions, which would be caused to move along paths closely resembling the lines of force. While it is probable that both hydrodynamic and electromagnetic forces influence the structure of the flocculi, it is important to learn, if possible, which of these is dominant.

As explained in another section of this report (p. 280), laboratory experiments on vortices have indicated that bipolar $H\alpha$ flocculi, if of hydrodynamic origin, should exhibit a characteristic configuration, the chief features of which are an arched structure on one side of the axis of the group and a more nearly radial structure on the opposite side. From the known direction of rotation of the spot vortices, it follows that the arch should lie above the axis (toward the poles) in the case of high-latitude groups and below the axis (toward the equator) in the case of low-latitude groups.

In Mr. Ellerman's hands the 13-foot spectroheliograph has yielded many photographs of $H\alpha$ flocculi of the finest quality, surpassing any we have obtained previously. The presence of many small spots in active bipolar groups usually complicates the structure, and makes comparison with our artificial bipolar vortices somewhat difficult. In many cases, however, the structure closely resembles that of our bipolar smoke vortices, suggesting a hydrodynamic origin; but in other instances the appearance of the lines of force of a magnetic field is more clearly suggested. It is thus evident that much more work will be necessary before definite conclusions can be drawn.

We are indebted to Professor Frost for the use of some excellent negatives of $H\alpha$ flocculi made by Professor Fox with the Rumford spectroheliograph of the Yerkes Observatory.

THE DARK "FILAMENTS" OF THE HIGHER SOLAR ATMOSPHERE.

The completion of the 60-foot tower telescope serves another useful purpose in permitting us to resume high-dispersion work with the spectroheliograph, which has been seriously delayed by various causes. The images obtained with the center of *Hα* show admirably the dark "filaments" so successfully photographed by M. Deslandres, and as they also give the prominences at the limb equally well, a comparative study of these phenomena has been undertaken. The suggestion made when these "filaments" were first found at the Yerkes Observatory in 1903, viz, that they represent prominences seen in projection on the disk as comparatively cool absorbing masses, may thus be tested more fully.

MAGNETIC FIELDS IN SUN-SPOTS.

The numerous sun-spots which have appeared since the recent revival of solar activity have given opportunity for a variety of investigations of their magnetic phenomena. These have been greatly facilitated by the large solar image of the 150-foot tower telescope and the high dispersion of the 75-foot spectrograph. 384 negatives of spectra, containing from 2 to 6 exposures each, were made with the instrument during the year by Messrs. Ellerman, Monk, Colby, Capon, and Luckey; 261 of these were for the general magnetic field of the sun. 113 negatives of spot spectra, including good third-order plates covering the region $\lambda 5200$ to $\lambda 6600$, were also obtained, while the remaining 10 negatives were for miscellaneous purposes. A complete quantitative study of the many excellent negatives of spot spectra is now in progress, but some miscellaneous results of interest may be mentioned here.

PHASES OF THE ZEEMAN EFFECT.

The use of a compound quarter-wave or half-wave plate in conjunction with a Nicol prism for photographing spot spectra is extremely useful in bringing out the various phases of the Zeeman effect. The elliptically polarized red and violet components of lines in spots near the center of the sun are alternately cut off by the odd and even strips (usually 1 mm. wide) of the quarter-wave plate, while the phenomena of plane polarization are equally well shown with the half-wave plate in spots near the sun's limb. In the latter case only the two outer components of a triplet appear on the odd strips, while the central component appears alone on the even strips.

The above phenomena are in harmony with the view that the lines of force at the center of the spot vortex are nearly radial to the sun's surface. The presence of the central components of triplets in spots near the center of the sun may indicate, however, that they are not exactly radial—a point which is being investigated further. In spots near the limb it is interesting to observe the changes in the polarization phenomena as the slit passes from the inner to the outer

edge of the penumbra. These are apparently due to the difference in the inclination of the lines of force to the line of sight on opposite sides of the spot.

The dispersion and resolution of the 75-foot spectrograph are sufficiently high to show as many as five well-separated components in some lines, while in other cases the compound quarter-wave plate leaves no doubt as to the presence of components not completely resolved. In this way the detailed comparison with Mr. Babcock's admirable laboratory photographs of the Zeeman effect, which is now in progress, can be made very satisfactorily, in spite of the comparatively weak fields in spots.

A remarkable characteristic of certain photographs is a distinct shift of the central line of some triplets on alternate strips of the quarter-wave plate. This would naturally be taken to indicate that the edges of this central component are circularly polarized in opposite directions, but I am not aware that any such effect has been observed in the laboratory. The phenomenon will be fully investigated.

SUN-SPOT POLARITIES.

The polarity of a sun-spot, which may be assumed to give the direction of rotation of the spot vortex, is indicated by the transmission of the red or violet component of a Zeeman triplet by a given strip of the quarter-wave plate. With the large solar image it is possible to apply this test, both visually and photographically, to the smallest spots, and thus to check the tentative conclusions announced in the last annual report. These have been abundantly confirmed, both as regards the general characteristics of bipolar spot groups and the direction of their rotation in the northern and southern hemispheres of the sun.

With rare exceptions, possibly confined to the region of the solar equator, the spots lying near the opposite ends of a physically united group are of opposite magnetic polarity. Minor companions of either sign may be present, but opposite polarities strongly predominate at opposite ends of the group. A quantitative study is being made of the weaker fields present in the entire region surrounding spot-groups.

This result, which is now based on the observation of over 100 spots, has rendered possible a much more complete study of the rule of polarities, which is found to be as stated last year. In bipolar groups of low latitude the preceding spot vortices rotate counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere, as in the case of terrestrial cyclones and tornadoes. In high latitudes, on the contrary, the preceding spot vortices rotate clockwise in the northern hemisphere and counter-clockwise in the southern hemisphere. In all cases the direction of rotation for the following members is opposite in sign.[1]

[1]These conclusions, which refer to the low-lying spot vortices, are based on the assumption that the sign of the revolving charged particles is always the same. This assumption, however, may prove to be incorrect, as results obtained since this report was written indicate that the vortices shown on spectroheliograms taken with *Hα* are rotating in the *same* direction as before the minimum.

The hypothesis that the preceding members of a bipolar spot group represent the opposite extremities of a semicircular vortex ring has recently led to some laboratory experiments described on another page (p. 280). On this hypothesis bipolar spots should exhibit proper motions at right angles to the axis of the group, which usually makes only a small angle with the solar equator. The direction of motion, as determined from the above law of polarities, should therefore be toward the equator for low-latitude spots and toward the poles for high-latitude spots. Carrington, and more recently Dyson and Maunder, found proper motions (for all spots, single and multiple) corresponding in sign with this requirement. But the inclusion of single spots and the small magnitude of the motion in latitude renders the agreement of doubtful significance, and further study of this question will be necessary.

The rule of polarities, in conjunction with the vortex experiments, also provides the means of predicting the configuration of bipolar flocculi in high and low latitudes, on the assumption that this is determined by hydrodynamic forces (see p. 256).

GENERAL MAGNETIC FIELD OF THE SUN.

Our preliminary work on the general magnetic field of the sun served to establish the existence of the field and to determine its intensity and polarity. A second series of observations, besides giving improved determinations of intensity, increased the number of lines showing the field from 4 to 25, and indicated which lines should be chosen for further work of the highest precision. Up to this time scattered observations, made during the broken weather of the rainy season, served very satisfactorily; but for the accurate determination of the inclination of the sun's magnetic axis a continuous series of observations, well distributed in latitude and longitude, is required. Accordingly a large number of photographs of spectra were taken with the 150-foot tower telescope and 75-foot spectrograph during the summer of 1915. These covered a period of 110 days, of which 3 days were lost on account of clouds, and 2 days because of necessary repairs to the instruments. Very few spots appeared on the sun during this period, and the occasional spectra taken sufficiently near these to feel their magnetic influence in any degree were rejected. This large collection of photographs is thus admirably suited for the difficult task of determining the inclination of the sun's magnetic axis and the period of its revolution about the axis of rotation.

During the present year Mr. van Maanen has measured the magnetic displacements of the three lines $\lambda 5247.737$, $\lambda 5300.929$, and $\lambda 5329.329$ on 819 of these spectra, representing 26 days distributed over 6 weeks. The completion of the work will require some time, as the measurement is very laborious and difficult. This will be appreciated when it is remembered that the *maximum* displacement (at latitude $+45°$)

is 0.001 A, and that we are here concerned with quantities of the second order.

The reductions have been kept up to date by Miss Wolfe and Miss West under the direction of Mr. Seares, but of course no definitive values can be given until all of the measurements and the least-squares solutions have been completed. From present indications the inclination and period will not differ greatly from 5° and 30 days (synodic), respectively.

The publication of the complete results for intensity of field for the 25 lines mentioned above has been greatly delayed, owing to difficulties in measuring some of the lines with the Koch machine. These measurements are necessary in order to determine personal equation and the possible effect on the displacement of the width and character of the line. The difficulties are mainly due to the narrowness of the strips of spectra, which causes the silver grain to play a conspicuous part in the records. It is expected, however, that satisfactory results will be obtained by a slight modification of the method.

THE STARK EFFECT.

If the general electric field of the sun is sufficiently intense to give an appreciable Stark effect at the hydrogen level, the edges of the hydrogen lines should be plane polarized and thus capable of being cut off with a Nicol prism. An investigation has been made by Mr. Hale and Mr. Babcock to test this question. Photographs of the hydrogen lines near the sun's limb were taken with the 75-foot spectrograph, using a Nicol prism and compound half-wave plate above the slit. Measurement of $H\alpha$ and $H\beta$ on curves made with the Koch microphotometer showed no appreciable difference in width for the odd and even strips. From Stark's results we may therefore conclude that the intensity of the sun's electric field does not exceed 200 volts per centimeter at the hydrogen level.

In order to extend this investigation to sun-spots, it is necessary to determine the Stark effect for the lines of iron, chromium, titanium, and other elements which lie at a comparatively low level in the solar atmosphere. As stated elsewhere, complete laboratory equipment has been provided for this purpose, and it is hoped that both the solar and laboratory phases of this research, which have been held back by the pressure of other work, may soon be in full progress.

PRESSURE AND MOTION IN THE SOLAR ATMOSPHERE.

Mr. St. John's investigations bearing upon pressure and motion at different levels in the solar atmosphere are still in progress. The results on the spots of the new cycle confirm the observation of the outflow of the low-lying vapors and the inflow of those at the highest levels. The long plates (90 cm.) allow a range of 600 A to be covered with the 75-foot spectrograph and permit overlapping series to

connect widely different spectral regions for comparing displacements and wave-length. Vertical motions of the calcium vapor, shown by the displacements of the H and K lines, appear to be characteristic of spots, while there is little evidence of such motion given by the *Hα* lines of hydrogen. Particular attention is being given to the comparative study of the spectrum of the limb and the center of the sun, and to the identification of the great number of new lines appearing only at the limb.

Further observations bearing upon possible evidence of anomalous dispersion and the Einstein effect in the solar atmosphere are being carried on. It has become evident that, in any effort to push determinations to the third decimal place in comparing solar and terrestrial sources by the spectrograph, it is necessary to make the exposures rigorously simultaneous. Both the 150-foot and the 60-foot tower telescopes are now equipped for this work, and the completion of the interferometer installation in the 60-foot tower furnishes additional means for checking old and of obtaining new data. Notwithstanding the massiveness (4.5 tons), the stability, and the constant-temperature condition of the 75-foot spectrograph, it is necessary to leave the instrument completely undisturbed during the comparison of different sources.

SOLAR ROTATION

During the year four series of plates have been made with the first order of the 75-foot spectrograph (scale 1 mm. = 0.7 A) for the investigation of the solar rotation by Mr. Adams and Mr. St. John. The light has been taken from a point 3 mm. within the edge of an image 410 mm. in diameter. These include the regions:

(*a*) In the violet, λ 4123-λ 4340.
(*b*) In the green, λ 5018-λ 5316.
(*c*) In the red, λ 6300-λ 6563.
(*d*) The fourth series, λ 5018-λ 5316, contains spectra of the two limbs and the center for the purpose of comparing the rotation values for the northern and southern hemispheres, and is also available for obtaining limb-center displacements

The plates of series (*a*) and (*b*) have been measured for zero latitude. The measurements confirm the results previously obtained at this Observatory in showing differences depending upon the intensities of the lines, the stronger lines yielding the higher relative values. For the three magnesium lines of the *b* group (mean intensity 22), the equatorial velocity is 2.043 km. per second, while for 22 lines of intensity 1 to 7 the mean equatorial velocity is 1.934 km. per second. These results depend upon filar micrometer measurements made by three observers, the three series being in practical agreement.

An effect depending upon the intensity of the lines is shown by the observations of 1906–07, 1908, and 1914–15 at this Observatory, which is not apparent in the determinations at other observatories. In order to eliminate systematic errors possibly inherent in filar micrometer measurements of lines differing widely in solar intensity, the displace-

ments between the east and west limbs for some typical lines have been measured by means of curves obtained with the Koch microphotometer. The preliminary results from 6 plates for three lines of intensity 2 and the two magnesium lines $\lambda 5172$ and $\lambda 5183$ show systematic differences in displacement of the same order as those shown by the filar micrometer measurements. The displacements in millimeters found by the filar micrometer are given in the upper line, while those determined from measurement of the curves made by the microphotometer appear in the lower line of the summary. The data refer to the same plates.

$\lambda 5165$	$\lambda 5225$	$\lambda 5226$	Mean.	$\lambda 5172$	$\lambda 5183$	Mean.
0.0842	0.0861	0.0858	0.0853	0 0892	0.0894	0.0893 mm.
0.0852	0.0859	0 0853	0 0855	0 0886	0.0878	0.0882

When the equatorial velocities obtained from the displacements of the unenhanced lines are grouped according to their intensity, a systematic variation is very apparent.

Intensity..............	1.0	2.0	3.6	6.5	22
Number of lines.........	2	5	5	4	3
Equatorial velocity......	1.924	1.933	1.937	1.954	2.043

The equatorial velocities for enhanced lines are slightly lower than for unenhanced lines of the same mean intensity, a result in harmony with that from the two earlier investigations. For 6 enhanced lines of mean solar intensity 3.2, the rotation value is 1.928 km., while for 5 unenhanced lines of mean intensity 3.6, it is 1.937 km.

From the 1906–07 series of Mount Wilson observations, the equatorial velocity found was 2.064 km., while that from the 1908 series was 2.053 km. In view of the still lower value obtained from the current series (1.949 km.), and the generally low values found by recent observers at epochs falling between the two last Mount Wilson series, the question of the constancy of the solar rotation may be seriously raised. This systematic decrease in the values found for the solar rotation emphasizes the need of entering upon a series of observations extending over a considerable period of time. Such a series has been begun, and it is intended to obtain plates in zero latitude under the same observing conditions each month for some years to come.

A more extended series of measurements based upon the curves obtained by the microphotometer is under way. If the preliminary results for the magnesium lines are confirmed, the method will be employed for a larger number of lines. The method appears eminently fitted to determine whether the variations found by the filar micrometer are real or are occasioned by the personal characteristics of the observer.

INVESTIGATIONS OF STARS AND NEBULÆ.

OBSERVING CONDITIONS.

Observing conditions at night for the year ending August 31, 1915, were somewhat less favorable than during the two previous years. The 60-inch reflector was in use 153 entire nights and during a part of 111 nights, while on 101 nights no observations could be made. Out of 3,591 hours of darkness the instrument was in use 2,006 hours, or 55.9 per cent of the total night-time. There were 1,585 hours when observations were interrupted because of weather conditions and 56 hours for silvering, repairs, etc. Table 1 gives the statistics for each month:

TABLE 1.

Date.	Hours of darkness.	Hours clear.	Hours cloudy.	Hours lost silvering and repairing.	Hours of exposure time.	No. of photographs.	Observations.		
							All night.	Part of night.	None.
1914									
September....	295	231	64	3	158	388	20	7	3
October.....	336	224	112	7	146	270	16	9	6
November....	330	235	95	1	172	263	16	10	4
December....	346	84	262	0	63	91	2	11	18
1915									
January......	346	113	233	2	85	105	3	13	15
February....	308	90	218	0	70	79	4	8	16
March.......	324	134	190	15	85	101	6	14	11
April........	286	88	198	0	54	86	4	9	17
May.........	266	136	130	21	97	98	12	9	10
June...	230	176	54	6	121	163	15	14	1
July........	255	229	26	1	168	188	25	6	0
August.......	269	266	3	0	198	213	30	1	0
Totals..	3,591	2,006	1,585	56	1,417	2,045	153	111	101

The total exposure time for the year was 69 per cent of the observing time and 40 per cent of the night-time. Average exposure per plate, 42 minutes.

As usual, the month of August gave the highest percentage of good weather, only 3 hours being lost on account of clouds. This month also gave very little wind, which was light on 9 nights and moderate

TABLE 2.

Seeing.		Wind.	
<1 to 1..............	63 nights.	Very high.....	7 nights.
1 to 2...............	73	High............	23
2 to 3...............	109	Brisk...............	36
3 to 4+............	25	Moderate.......... .	51
		Light...	127
		Calm...............	88

Wind percentage: High, 9; brisk and moderate 26; light to calm, 65.

1 night, while 21 nights were calm. The poorest observing weather was in December. Table 2 gives a record of the seeing, on a scale of 1 to 5, together with the wind record as observed each night:

The average range of temperature in the dome between opening and closing time was 6° C. The highest temperature recorded was 30.6° C. on August 19, while the lowest was −3.5° on February 20.

DIRECT PHOTOGRAPHY.

Mr. Ritchey, who resumed photographic observations of nebulæ with the 60-inch reflector in May, has obtained the following long-exposure negatives at the Newtonian focus:

N. G. C. 6960, exposure 12 hours.	N. G. C. 5457, exposure 9 hours.
N. G. C. 6946, exposure 9 hours.	N. G. C. 224, exposure 9 hours.

During the year Mr. Pease has obtained the following photographs at the Newtonian focus of the 60-inch reflector:

Spiral nebulæ, left hand. .	N. G. C. 1186, 3666, 3938, 5921, 5857–9.
Spiral nebulæ, right hand .	N. G. C. 5660, 5666, 5669. (These appear on a single plate)
Gaseous nebulæ .	N. G. C. 6309, 7008.
A single plate contains .	N. G. C. 2825, 2826, 2827, 2829, 2830, 2831, 2832, 2833, 2834, 2839, and 27 others.

Of the last group, 6 are spindle nebulæ with nucleus, 3 elongated with no nucleus, and 28 are nebulous spots or stars; the field is about 36 minutes of arc on a side.

DIRECT DETERMINATION OF PARALLAXES.

During the past year 440 plates have been taken by Mr. van Maanen with the 80-foot focus combination of the 60-inch reflector; on many of the plates there were 2 exposures, making a total of 603 exposures, of which 427 were for the determination of parallaxes.

For 17 stars, each with from 10 to 18 exposures, the measures and reductions have been finished. The mean probable error of a parallax is 0″.0055. Although present indications point to the absence of large systematic errors, this question can not be fully discussed until more material is available.

During the middle of the night, when the parallax factors for stars near the meridian become very small, the instrument has been used for photographing stars with large proper motions ($>0''.50$ a year), the purpose being to detect possible companions. First-epoch plates have been secured for 66 stars, with exposures of 15 minutes, which show stars to approximately the fourteenth magnitude. After an interval of one or two years it should be possible to detect stars of common proper motion.

As the published lists of stars of large proper motion were far from complete, Mr. van Maanen has collected the data from all sources published as late as 1914.

STELLAR PHOTOMETRY.

The observational part of the investigations in stellar photometry by Mr. Seares and Mr. Shapley includes 764 photographs, all made with the 60-inch reflector and distributed as follows:

Variables	270
Clusters	171
Selected Areas	189
Orion Stars	80
Miscellaneous	54
Total	764

Standard Polar Magnitudes

The investigation by Mr. Seares of the magnitudes of stars near the pole, including those of the North Polar Sequence, has been completed. A summary of the results, including a list of photographic and photovisual magnitudes for about 300 stars, has been published as *Mount Wilson Contribution* No. 97, and all of the tabular data for the final publication of the results have been compiled. These include photographic magnitudes from 2.5 to 20.1 for about 600 stars, and photovisual results from 2.1 to 17.5 for about one-half this number of objects.

The appearance of Miss Leavitt's investigation in volume 71 of the *Harvard Annals* has made it possible to compare in detail the Harvard and Mount Wilson results. The large divergence between the two scales in the region of the faint magnitudes is due to two circumstances affecting the Harvard reduction of photographs made at Mount Wilson with the 60-inch reflector: first, the neglect of the distance correction; second, the application of a correction depending on the order of exposure.

The importance of the distance correction and its influence upon the scale have been discussed in previous reports. The first and last exposures on a plate, although of equal duration, often differ systematically. Some of the Mount Wilson plates showed such differences, and in the Harvard reduction it was assumed that the intermediate exposures, which were used for the derivation of the scale, were affected proportionally to the time which had elapsed since the beginning of the first exposure. It seems, however, that this assumption is unjustifiable. The systematic effect is probably confined to the first exposure, which does not enter into the scale, while apparently the intermediate exposures require no correction. With allowance for these two circumstances, the Harvard and Mount Wilson measures of the plates for the faint stars give identical results for the scale.

The determination of color indices for the Polar Sequence Stars has made it possible to complete the reduction of the Harvard magnitudes to a homogeneous color system. The corrections thus introduced improve the agreement of the Harvard and Mount Wilson scales, and,

with the application of the final zero-point correction, the outstanding difference between the sixth and tenth magnitudes, which originally was about 0.4 mag., has been decreased to 0.24 mag.

In an effort to locate the source of this remaining difference, the Harvard data relating to the stars brighter than the tenth magnitude were re-reduced wherever possible by methods which did not involve the direct use of the reduction constants of the screens and diaphragms with which the photographs were made. This was accomplished by assuming the validity of the scale between the tenth and fifteenth magnitudes and transferring the same to the region of the brighter stars. In this manner the agreement of the Harvard and Mount Wilson results was extended from the tenth upward to the eighth magnitude. The remaining discordance of about a quarter of a magnitude is thus thrown upon the stars between the sixth and the eighth magnitudes.

Magnitudes for the Selected Areas.

In this investigation, which is in the hands of Mr. Seares, about three-fourths of the diaphragm plates necessary for the determination of the scales of the individual areas have been obtained. In the meantime, the intercomparison of the areas with each other and with the pole for the derivation of the zero-point corrections has been begun. About 80 plates for this part of the investigation have been obtained. The reductions have progressed satisfactorily, although the large number of stars registered in some of the richer fields makes the work slow. 176 plates have been completely measured; 15 plates have been measured once. For 34 areas the measures are complete, while for 24 others one-half of the work is finished. The reductions, up to and including the relative magnitudes, are complete for 22 areas. Although these are mainly in the intermediate or higher galactic latitudes, the fields (diameter 23′, exposure 15 minutes) show an average of 125 stars per area. It is of interest further to note that 4 areas near the Milky Way (mean galactic latitude = 4°) show an average of 1,400 stars per field.

Magnitudes and Colors in Clusters.

The completion of the derivation of standard magnitude scales permits the application of photometry to the determination of the colors of faint stars in special regions of the sky. A systematic investigation of the photographic and photovisual magnitudes in open and globular clusters has been begun by Mr. Shapley and nearly a dozen clusters have been compared with the North Polar Standards. The measurement and reduction of the plates is well under way, and a catalogue of the magnitudes and colors of 1,302 stars in Messier 13 has been completed. The results obtained bear directly on such questions as the distance of globular clusters, the relation of color to absolute magnitude, the absorption of light in space, and the absorption peculiar to

the dense central regions of clusters. Incidentally a number of plates have been made for the purpose of studying the variable stars in globular clusters.

Computations of the Orbits of Eclipsing Binaries.

Several investigations relating to eclipsing binaries have been undertaken by Mr. Shapley, chief among which are determinations of spectroscopic and photometric orbits for RX Herculis and of photometric orbits for Algol. For the former it was possible to obtain the spectroscopic orbits of both components from only 3 plates, as the light curve had already furnished data for a number of the orbital elements. The derivation of the orbit of Algol involved the first application of the hypothesis of intermediate degrees of darkening at the limb. The computations also considered the possible effect on the light-curve of the third body in the system.

Other computational work includes the formulation of simple relations for the upper and lower limits of the mean density of eclipsing variables, the discussion of low densities among second-type stars, and the revision of certain double-star orbits.

Cepheid Variables.

Observations on faint variable stars by Mr. Shapley with the 60-inch reflector have included the investigation of the light and color changes of a few stars of the "cluster type." For XX Cygni, which is the shortest-period variable on record, the observations and reductions have been completed. The main result is the proof from Mount Wilson and other observations of the changing shape of the light curve. The lack of regularity in the curve, together with a number of other considerations based on peculiarities of the light and velocity variations of Cepheid and "cluster-type" variables, leads to the conviction that the long-standing hypothesis that Cepheids are double stars is insufficient. In fact, the evidence now in hand shows the impossibility of any theory so far proposed with that assumption for its basis.

STELLAR SPECTROSCOPY.

The results of an investigation by Professor Kapteyn and Mr. Adams, completed in the autumn of 1914, have enlarged to a considerable extent the problem of radial velocity observations with the Cassegrain spectrograph. The main feature of this research, to which reference was made in the last annual report, was the proof of the existence of the two star-streams among the very distant stars of the solar type of spectrum. In addition, however, two other results were derived: first, a relationship between radial velocity and proper motion for the stars of the F, G, K, and M types of spectrum; second, a certain amount of evidence tending to indicate, in the case of the K stars at least, an increase in radial velocity with decrease in brightness. The

importance of investigating the second question has led to the compilation of an extensive list of stars with proper motions comparable with those of stars for which the radial velocities have already been determined, but averaging about 2 magnitudes fainter. This list, consisting of about 160 stars of magnitudes 7.5 to 9.0, now forms one of the principal portions of the radial-velocity program.

Observations have been continued throughout the year on the large proper-motion stars with measured parallaxes; on numerous stars of types A, F, G, K, and M with very small proper motions; and on a considerable number of miscellaneous stars, including those suspected of belonging to the Perseus group.

The number of photographs obtained during the year is 810, distributed as follows:

Small proper-motion stars, types A to Mc	553
Parallax and large proper-motion stars	113
Selected Areas	30
Perseus group	29
Absorption of light in space photographs	23
Miscellaneous	62

For a large majority of the photographs the 46 cm. camera and one prism have been used. A few very faint stars have been photographed with a camera of 18.3 cm. focal length, but the resultant velocities are necessarily approximate. Some slight modifications have been made in the spectrograph during the year. The most important of these is the addition of a guiding eye-piece mounted on cross-slides below the slit to enable the observer to select a star in the field of view of the telescope, and thus guide during exposures on objects too faint to be seen distinctly with the usual reflecting slit arrangement.

Radial Velocities.

A list of the radial velocities of 500 stars on which three or more observations have been obtained has been prepared for publication recently. The spectral types of these stars are as follows:

B	93	F	38	K	88
A	140	G	96	M	45

The B and A type stars in this list were selected mainly for the purpose of providing the data for a more accurate determination of the elements of the two star-streams, and the results will be used for this object in a future discussion by Professor Kapteyn. The F to M type stars are made up of two classes: stars of large proper motion and in most cases of measured parallax, and stars of exceptionally small proper motion and hence of great average distance. A comparison of the radial velocities, corrected for the sun's motion, of the small and the large proper-motion stars shows a rapid increase in velocity with proper motion for the F, G, and M stars, and probably a corresponding increase for the B and A stars, although large proper motions

are very rare among stars of these types. This result agrees with that found by Kapteyn and Adams for the K stars.

A question of special interest is that of the variation of radial velocity with spectral type among the very distant stars represented in this list. If only those stars which have a proper motion of less than 0".030 are selected we obtain the results given in table 3 for the average radial velocities of the different types, corrected for the solar motion.

TABLE 3.

Spectral type.	No. of stars.	Average proper motion.	Average radial velocity.	Average radial velocity, corrected for stream-motion.
			km.	*km.*
B .	61	0".016	8 2	8 2
A	55	0 019	10 0	7 7
F .	20	0 011	10.1	8 8
G .	63	0 013	10 6	9 2
K	56	0 014	11 5	10.0
M	27	0 015	12.6	10 9

The last column of the table gives the average radial velocities with approximate corrections applied for stream-motion in accordance with the method due to Eddington. It is evident from these results that the change of radial velocity with spectral type is a very gradual one for these distant stars.

A feature of the radial-velocity determinations in the case of the stars with measured parallaxes is the large velocity of the stars of low absolute brightness. The average radial velocity of 16 stars with absolute magnitudes below 8 on a scale on which the sun is 5.5 is 36 km. This may be compared with the value of 24 km. for 135 stars of large proper motion and measured parallax.

Among the other radial velocity results found during the year reference may be made to the following:

(1) The discovery of 21 spectroscopic binaries. Six of these show the presence of two spectra on the photographs.

(2) Large radial velocities have been found for the following stars:

TABLE 4.

	Mag.	Spec.	Velocity.
			km.
W. B. 3^h617. .	7 2	F5	+114
A. Oe. 14318 .	9 6	G	.
W. B. 17^h514 .	8 6	F	−148
A Oe. 20452 .	8 1	G0p	−179

(3) Of 32 stars observed in the *h* and χ Persei clusters 20 have been found to have a common radial velocity of about −40 km. Five other

stars probably belong to the group, but as yet only single observations are available for them. The average spectral type of the stars found to belong to the group is B 6.

(4) The radial velocities of the Andromeda nebula and the bright line nebula N. G. C. 1068 have been determined from photographs taken by Mr. Pease with a small spectrograph at the primary focus of the 60-inch reflector. They are as follows:

Andromeda nebula..........	−329 km.
N. G. C. 1068...............	+765

Absolute Magnitude Effects in Stellar Spectra.

Photographs of the spectra of pairs of stars taken during the year confirm the conclusion referred to in the last annual report that, of stars having the same types of spectra, the more distant stars are fainter in the violet portion of the continuous spectrum. The probability that at least a part of this effect is due to the greater intrinsic brightness of the more distant stars has been increased to some extent by recent observations. On account of uncertainties in parallax determinations, it is difficult to select suitable pairs of stars of known distance. Accordingly the question is now being investigated with the aid of observations on two lists of selected stars:

(1) Faint and bright stars in the Hyades which are known to belong to the Taurus cluster. Since these stars are at nearly the same distance, a difference in the violet portion of the continuous spectrum for stars of the same spectral type must be ascribed to the effect of intrinsic brightness. The exceptionally unfavorable observing weather during the winter made it possible to obtain only a few photographs of these stars. So far as the evidence extends it indicates that the fainter stars are relatively stronger in the violet part of the spectrum.

(2) The observing list of small proper-motion stars with magnitudes between 7.5 and 9 affords the opportunity of making a comparison of the intensity of the spectrum of these stars with those of stars of the same average proper motion but about 2.5 magnitudes brighter, which have already been observed for radial velocity. In the average the two groups of stars should have closely the same distance, and the fainter stars apparently should also be the fainter stars intrinsically. The results so far obtained indicate that the fainter stars are stronger in the violet portion of the spectrum.

The method of using the relative intensities of certain spectral lines as a criterion of absolute magnitude, which was developed mainly by Mr. Kohlschütter, and described in the last annual report, has been continued during the year. The results found fully confirm those obtained previously, and appear to warrant the use of this means for the actual determination of individual parallaxes. At present the chief need is a more accurate standard of reference for the very distant stars which, in the absence of parallax measures, has been based upon the

formula connecting proper motion with parallax. The observations of Mr. van Maanen on small proper-motion stars will soon provide the material for a revision of this standard, which now appears to give values of the parallax that are too small. As an illustration, spectrum observations on 7 of the stars measured by Mr. van Maanen give the following comparison: Measured parallax, $+0''.013$; parallax from proper motion, $+0''.006$; parallax from spectrum, $+0''.004$. For the large proper-motion stars of measured parallax the agreement, as would be expected, is distinctly better.

The Spectrum of Nova Geminorum No. 2.

Photographs of the spectrum of Nova Geminorum of 1912, made by Mr. Pease with the small spectrograph at the principal focus of the 60-inch reflector, show that the spectrum of this star has now passed from that resembling a planetary nebula into that of a Wolf-Rayet star. Similar results were found for Nova Aurigæ of 1891 and Nova Persei of 1901 from photographs made in 1913–14. Special interest attaches to the result in the case of Nova Geminorum No. 2, since the observations form essentially a continuous series from the time of its outburst as a temporary star and record the changes in its spectrum through the various stages of its development into what is probably its final state, that of a Wolf-Rayet star. The conclusion that at least a portion of the Wolf-Rayet stars are Novæ in the later stages of their history is made highly probable by these results.

A remarkable feature of the observations was the disappearance of the chief nebular line at $\lambda 5007$ previous to that of the second nebular line at $\lambda 4960$. These lines have always been associated with each other and vary in intensity with one another in planetary nebulæ. They are almost certainly due to the same radiating gas, and the difference in their behavior in this case argues a highly exceptional state of physical conditions.

The Spectrum of T Tauri.

A low dispersion photograph of the spectrum of T Tauri shows that the spectrum of this irregular variable is composite in character. The spectrum of the star proper is of type approximately F5, but superposed upon it are narrow, bright lines which appear to extend beyond the continuous spectrum of the star. There seems to be little doubt that the star is surrounded by an extensive atmosphere similar to that of the star B.D.+36°3639 discovered by Professor Campbell some years ago. Direct photographs show a nebulous appendage about 4″ in diameter somewhat eccentrically situated in reference to the star.

Miscellaneous.

The spectra of several stars of very low luminosity have been photographed during the year. All of these, with a single exception, have proved to be of types K5 to Mb. The exception is the comparison

star o^2 Eridani, which is of type A0, a result previously indicated by the color-index determinations of other observers.

Several attempts have been made to photograph the spectrum of the companion of Sirius. Although no conclusive results have been obtained, photographs secured under observing conditions which would certainly show the spectrum of this star with the exposure times used give no indication of the presence of any spectrum different in type from that of Sirius. The hypothesis might at least be entertained that the light from the companion is in part reflected light and that this may account for its low luminosity. Two direct photographs obtained by Mr. van Maanen with and without the use of a color screen also indicate no marked color index for the companion star.

A photograph of the spectrum of Messier 15, made by Mr. Pease with the small focal plane spectrograph, shows the spectra of about 18 stars ranging generally in type from A5 to F5, with one star about G0.

With the same instrument Mr. Pease has also photographed the spectrum of the Andromeda nebula, the total exposure time amounting to 34 hours. The spectrum is of the G type, the more prominent lines extending over a minute of arc on either side (E–W) of the nucleus. As already stated, the mean velocity from 9 lines measured by Mr. Adams is −329 km., reduced to the sun. There seems to be no evidence indicating either the presence of bright lines or of a rotational displacement.

The spectra of several planetary nebulæ were photographed by Mr. Pease to determine the relative intensities of various lines with a view to possible work with a Fabry-Perot etalon.

PROFESSOR KAPTEYN'S INVESTIGATIONS.

This year attention has been given mainly to the three following subjects:

(1) *The relations between the proper motions and the radial velocities of stars of the spectral types F, G, K, and M* (jointly with Mr. Adams).—The question was mentioned in last year's report. Since then preliminary results have been published in the *Proceedings of the National Academy of Sciences*. The distribution of the peculiar velocities has been investigated further, and results have been obtained from which both the solar and the stream motions are completely eliminated. They give a satisfactory explanation of the change of the mean radial velocity with the proper motion. Traces were also found of a change of velocity with absolute brightness, but as the evidence was very slender, a list of stars has been drawn up for the purpose of settling the question. The stars of this list are now under observation.

(2) *The determination of the average parallax of the stars of spectral types N and O.*—Both of these classes of stars, but especially the latter, are very strongly condensed towards the Milky Way. It seems

natural to conclude that they must be very distant, consequently also very luminous. A direct confirmation of the great distance is, however, exceedingly desirable. At Professor Kapteyn's request the observatories of the Cape of Good Hope and of Leiden courteously undertook the observation of all the stars of these types not lately observed, for which there are older observations promising a tolerable determination of the proper motion. The new positions having been received, all the observations, old and new, were collected and proper motions were derived. From the parallactic motions the parallaxes were found as shown in table 5.

TABLE 5.

	π	No. of stars.
Type N ..	+0.″0022	55
Type O....	+0.0005	35

For the N type another determination has already been obtained from other data (*Astrophysical Journal*, 32, p. 93, 1910). The enormous distances implied by these numbers will best be appreciated by the comparison with similar determinations for other stars, given in table 6, in which the older and newer determination for the N stars are combined.

TABLE 6.

Spectrum.	Mean mag.	Mean π.	Probable error.	No. of stars.
B........	5.00	0″0068	±0.″0004	440
A..........	5.00	0.0098	0.0005	1,088
F, G, K.....	5 00	0 0224	0.0010	1,036
M......	5.00	0 0111	0 0020	101
N....	8 09	0.0012	0.0006	175
O...... ..	7 28	0.0005	0.0014	35
c stars......	4.50	0.0022	±0.0004	45

The last line relates to the stars called "c" by Miss Maury, occurring in Boss's catalogue. Hertzsprung was the first to call attention to the smallness of the proper motions of these stars. The determination here given is by Hertzsprung and Kapteyn and is now published for the first time.

(3) *Selected Areas.*—Now that Mr. Seares's photometric researches are approaching completion, it has seemed desirable to use his results for obtaining statistical data for the whole sky down to the lowest possible limit of magnitude. Such data based on a reliable photometric scale have long been felt as one of the most urgent desiderata in the study of the arrangement of stars in space. Accordingly photographs of all the Selected Areas from declination −15° to the North

Pole have been sent to Groningen, where they are now being measured. Both the positions and the diameters are being measured in duplicate. Near the Milky Way the fields are 15′ by 15′, in higher latitudes 20′ by 20′. A precision of about 1″ in each of the coordinates is aimed at. Of course the most important part of the work is the determination of the magnitudes, which is made possible with the aid of standards now being determined by Mr. Seares. Of the 139 areas, 107 have been completely measured. The total number of stars thus far is somewhat less than 40,000.

The fields are so small that our meridian catalogues do not furnish the necessary standards for position. These are therefore taken from the more comprehensive survey of the Selected Areas made with the aid of Harvard and Arequipa plates. These plates go down to about the sixteenth magnitude. The Mount Wilson plates will extend the range to about eighteenth magnitude.

PROFESSOR STÖRMER'S INVESTIGATIONS.

Professor Carl Störmer, of the University of Christiania, Research Associate of the Carnegie Institution of Washington, has completed his preliminary work on solar vortices for publication in the *Contributions*. The most striking result obtained is the extremely large electric field which would result if we consider the Zeeman effect in sun-spots due to a convection current of electricity. This seems quite irreconcilable with the apparent absence of the Stark effect, and the possibility that galvanic currents may play an important part in sun-spots must be given serious consideration.

These different working hypotheses will be further developed and settled when more material regarding the electromagnetic fields around sun-spots is obtained.

In the same paper are also developed some important consequences of the equations of motion of an electric particle in the electromagnetic field at high levels over the spot.

PHYSICAL LABORATORY.

INSTRUMENTS.

An important addition to the equipment of the laboratory is a complete outfit for the study of the Stark effect. This includes a Stark tube, filled with hydrogen, for which we are indebted to the kindness of Professor Stark, who had it made in his laboratory and tested it for us. The generating plant, installed in a small house erected behind the office building, consists of 40 one-half horsepower 550-volt D. C. General Electric motors (used as generators), mounted in 5 groups of 8 each, and driven by a 15-kw. 3-phase synchronous motor, run at 1,800 R. P. M. The lead wires are brought into a laboratory room in the basement of the office building, where the switches, voltmeter, tubes, spectrograph, and other instruments are

installed. A special form of Stark tube, permitting the easy substitution of anodes of different elements and the use of an auxiliary current for heating the anode, is under construction in our shop.

The Koch microphotometer has been completed and is in constant use. The permanent plate-holder, large enough to accommodate plates 8 by 40 inches, has been built, a new cylindrical lens and mounting have been provided, and a housing fitted over the mirrors in the projection system. A new precision electric contact, with fittings for automatically printing fiducial lines upon the plate, has been installed and tested. The battery has been tested after about a year's operation and is in excellent condition. The instrument has been used for investigations of the Stark effect on the sun, the general magnetic field of the sun, solar rotation, and the examination of many laboratory plates.

The 100-kw. transformer mentioned in the last report was installed after some delay by the Southern California Edison Company in the spring of this year and tested by them for long-continued service at full load. This has rendered possible the resumption of experiments with the "tube-arc" under improved conditions and furnishes greater power and flexibility for work with the electric furnace.

A vacuum-arc chamber has been constructed and used for a considerable time. It is provided with a water-cooling system and a pressure gage and may be operated indefinitely without difficulty. Pressures as low as 0.5 cm. of mercury are easily attained with it.

The apparatus for cathodic deposition of metals has been rebuilt to carry much larger currents. Films of silver, gold, platinum, and stellite of great uniformity have been produced by this means.

An improved form of hand-regulated arc lamp has been constructed. It combines great stability with precision of adjustment.

Eight new invar etalons for interferometry have been constructed and adjusted to about one-tenth of a wave-length. Five of them, having lengths of 1.0, 2.5, 5.0, 7.5, and 10.0 mm., respectively, are designed for use on the mountain, and the others, of lengths 2.5, 5.0, and 10.0 mm., for the laboratory. In addition, a new frame has been constructed for supporting the etalons intended for laboratory use. All the etalons are interchangeable. Tests show that with no protection from the usual variations in laboratory temperature these etalons suffer no change greater than 1 part in 10,000,000 in a period of about 2 hours.

An etalon mounting has been adapted for use at the focal plane of the 60-inch telescope and tested for constancy. Control plates taken 6 hours apart—between which the temperature varied about 5° C., the driving-clock was wound three times, and the apparatus was removed from the telescope and replaced—showed no loss of adjustment and a length variation of less than 2 parts in a million.

A Leeds and Northrup high-sensitivity galvanometer has been purchased. A further acquisition is a Wolff potentiometer with accessories, purchased by Professor H. S. Carhart on a grant from the Carnegie

Institution of Washington and deposited by him in the Pasadena laboratory. A Babinet compensator has also been purchased for use in testing mica preparations and for the study of polarized light in general.

A new compound $\lambda/4$ plate has been constructed and tested with the Babinet compensator. It has about 100 mica sections, each 1 mm. wide, adjusted for a relative retardation of $\lambda/4$ for λ6350. As far as λ4925 its retardation is practically a linear function of the wave-length. Retardations have also been measured for several of our other mica preparations.

A measurement has been made of the angular error between the axis of the screw of the ruling-engine and the plane of the ruby which is used as an end-thrust bearing. By means of a concave mirror of 36 feet radius of curvature, a high-power micrometer eyepiece, and a method involving twice the angle under consideration, it was found that the angle differs from 90° by about 0".05.

ELECTRIC-FURNACE SPECTRA.

The investigation of electric-furnace spectra by Mr. King has been continued for elements of special interest in the Observatory work, a detailed study of the cobalt and nickel spectra having been made according to the plan followed for other elements, together with a set of plates for the comparison of the effect of different vapor densities upon certain lines in the iron spectrum.

The photographs of the furnace spectra of cobalt and nickel have covered the range from λ3000 to λ7100 for temperatures ranging from 1850° to 2600°. Three complete sets of spectrograms, taken at approximately 2000°, 2300°, and 2600°, respectively, have been used to classify the spectrum lines according to the temperature at which they first appear and their rate of increase in intensity as the temperature rises. The lines classified on this basis number 840 for cobalt and 423 for nickel. The leading features of these spectra are similar to those previously noted in the study of other elements. For each of them, the furnace spectrum in the region of shorter wave-length is rich as compared with the arc spectrum, while toward the red the differences between arc and furnace spectra, especially for nickel, are very striking. As indicators of the temperature conditions in other sources, particularly various solar regions, the variations of the cobalt and nickel lines at different furnace temperatures promise to be of much service.

In the detailed publication, consideration is given to lines showing unusual types in the furnace, to the behavior of certain cobalt lines which have been classified as enhanced, and to lines relatively stronger in the furnace than in the arc.

THE TUBE-ARC SPECTRUM OF IRON.

A survey of the iron spectrum as given by the "tube-arc" was carried out by Mr. King following the installation of the 100-kw. transformer. The tube-arc is obtained by causing the resistor tube of

the electric furnace to burn apart at a selected point, producing a low-voltage arc with an initial current of 1,000 amperes or higher. Experiments with the improved equipment have confirmed the observations reported in 1913 as to the varying intensity distributions of lines of different elements, the tendency of the tube-arc to show a spectrum resembling the spark, and the dissymmetries imparted to many of the stronger lines. The last feature is notable in the iron spectrum. The stronger arc lines are generally reversed and distinctly unsymmetrical, with the red side stronger. The degree of this dissymmetry, which varies from a barely perceptible one-sidedness to a condition where only a trace of the violet side of the line is visible, has been found to be closely related to the behavior of the line under other physical conditions. Thus lines of small dissymmetry in the tube-arc are low-temperature lines in the furnace and show only moderate sensitiveness to pressure displacement. Lines which are very one-sided in the tube-arc are high-temperature furnace lines and are strongly displaced by pressure. There are important exceptions, however, to the correspondence between tube-arc dissymmetries and pressure displacements and the similarity is probably to be interpreted as a sensitiveness to displacing agencies of different character.

The Koch microphotometer has been used in registering a large number of curves for the tube-arc plates, which show the character and the degree of the dissymmetry for different classes of lines. It was also possible, by measuring the distances from the curves of standard lines in both the tube-arc and the ordinary arc, to determine the displacement of the intensity maximum of the unsymmetrical line. Measurements of the curves for strong iron lines in the blue gave displacements ranging from 0.015 to 0.040 A. This displacing action in the tube-arc is diminished if the vapor-density is decreased to such a degree that the line in question becomes narrow. Changes in vapor-density alone, however, do not give unsymmetrical lines or measurable displacements, this having been tested by measurements of electric-furnace spectra for large differences of vapor density. The effect appears to depend primarily on the discharge conditions of the tube-arc, but to be magnified if the line is given greater width through high vapor density.

Measurements of the microphotometer curves of a group of iron lines in the green-yellow show these lines to be displaced toward the violet in the tube-arc. The same lines have been measured by St. John and Babcock as displaced toward the violet at the pole of the iron arc, and the relative magnitudes of the dissymmetries for the tube-arc lines in general show a very close correspondence with their polar displacements.

In addition to bringing out the enhanced lines, the tube-arc intensifies the diffuse lines of iron, the appearance of the spectrum as a whole being very different from that of the ordinary arc.

COMPARISON WITH SPARK DISSYMMETRIES.

The unsymmetrical lines given by the disruptive spark were described in last year's report. These results have been closely compared with the tube-arc effects, additional photographs of the spark spectrum being taken for this purpose. In addition to iron, the tube-arc and spark effects for selected regions of the titanium spectrum have been compared. The resemblance between the dissymmetries in the two sources is very close throughout, indicating that the features of the tube-arc which make its spectrum similar to that of the spark are responsible also for the dissymmetries of the individual lines.

INVESTIGATIONS OF THE IRON ARC.

The study of the pole-effect in the iron arc has been continued by Mr. St. John and Mr. Babcock as in the preceding year. The list of affected lines now contains 286 which shift toward the red at the pole and 80 which shift toward the violet.

Additional evidence of the reality of the displacements has been secured: first, by confirming with the Koch microphotometer the measures made with the Hartmann instrument; second, by interferometer measures of the pole effect directly; and third, by superposing upon the iron spectrum the absorption spectrum of iodine vapor at low pressure. For this purpose the spectrograph slit was placed in coincidence with the axis of the enlarged image of the arc. The iodine vapor was contained in a spherical glass bulb, placed in the beam of light. It happens that absorption lines due to iodine fall upon some of the emission lines due to iron, and as the former are among the narrowest lines known, they serve as fiducial lines of the highest quality. With reference to them, unmistakable displacements of the maxima of the iron lines in passing from center to pole of the arc are shown upon our photographs.

A possible dependence of the pole-effect upon the density and temperature of the iron vapor has been examined by electric-furnace tests upon selected lines, with the result that no change of wave-length was shown either for a tenfold change of vapor density or for a temperature variation from 2100° to 2600° C.

The arc *in vacuo* has been tested for pole-effect at pressures of 0.5 cm. and 10.0 cm. of mercury. In general, the pole-effect disappeared under these conditions, although the length and current-strength of the arc were the same as those used under normal pressure. This would indicate that the fall of potential plays a minor rôle, if any, in producing the pole-effect. Further study of this question is to be made.

A comparison of the pole-effects at positive and negative poles with the relative luminosities of these regions in different parts of the spectrum shows no apparent relationship between the two quantities.

The possibility of an increase of pressure localized in the core of the arc and very near to the pole was soon recognized as a hypothetical

factor in producing the pole-effect. In attempting to make a comparison of the magnitude of the pole-effect with that of the pressure displacements for the same lines it was found necessary to obtain new values of the pressure effect which should be free from pole-effect. This was carried out by means of the vacuum arc and the arc at normal pressure, using both the grating and the interferometer, and taking light only from the center of the arc. The results show clearly that pressure alone is insufficient to account for the pole-effect, although it may play some part in its production.

Several parts of this investigation are still in progress, namely, extension of our study of the pressure effect, energy distribution in the arc for *d* lines, examination of velocities of vapors in the arc, attempts to develop a type of arc better suited for use as a standard source, tests of spectra of other elements for pole-effect, etc.

STANDARDS OF WAVE-LENGTH.

Improvements in both the secondary and tertiary standards of wavelength are being sought by Mr. St. John and Mr. Babcock with the aid of the interferometer and the plane grating. A number of such spectra have been taken both for iron and also for standardizing certain lines in one of the ultra-violet carbon flutings. Reductions are in progress upon this material. Means are now available for wave-length comparisons of high precision by two independent methods, namely, a plane-grating spectrograph of great resolving power provided with devices for simultaneous exposure to two sources, and quartz invar interferometers of the highest reliability.

THE ZEEMAN EFFECT.

Mr. Babcock's work upon the Zeeman effect has consisted mainly in the collection of additional data for iron, chromium, and vanadium. To this end 25 new photographs have been taken, most of which have been measured. 1,132 lines of iron, 1,089 of chromium, and 1,361 of vanadium have now been reduced to a standard field and tabulated, the increase during the year being 363, 186, and 718 lines for these metals respectively. On all but the weakest lines in these spectra two or more values are now available, generally in excellent agreement. The spectral ranges covered are $\lambda 2325$ to $\lambda 6678$ for iron, $\lambda 2307$ to $\lambda 6978$ for chromium, and $\lambda 2977$ to $\lambda 6625$ for vanadium, only a few small gaps remaining which will require additional plates.

REFLECTING POWER OF STELLITE.

A comparison has been made by Mr. Babcock of the reflecting pôwers of stellite and speculum metal over the region $\lambda\lambda 3200$–5800 by means of the 1-meter radius concave grating. Photographic densities were compared by means of the Hartmann microphotometer. The measures show distinctly higher reflecting power for stellite over the whole range of wave-length.

VORTEX EXPERIMENTS.

Mr. Hale and Mr. Luckey have been engaged in a series of vortex experiments bearing on the nature of sun-spots and flocculi. According to the tentative hypothesis employed, a single spot is represented by a columnar vortex, descending for some distance into the photosphere. To account, however, for the rapid decrease in the strength of the magnetic field above sun-spots, it is supposed that the electrons whose motion produces the field are confined to the upper portion of the vortex. As sun-spots are usually associated in pairs of opposite magnetic polarity, the experiment was tried of spinning a flexible wire helix, threaded with wooden disks to float most of the weight and increase friction, at high velocity in a tank of water. After some wandering, the lower extremity of the columnar vortex thus produced gradually turns up until it meets the surface, resulting in a semicircular vortex ring, the two extremities of which are assumed by the hypothesis to represent the two spots of a bipolar group.

Kelvin's approximate formula for the motion of translation of a vortex was tested in water by the use of a semicircular vortex ring, with paddles which can be driven at any desired velocity, suspended from a balanced pendulum. As already mentioned (p. 259) sun-spots in high and low latitudes are found to move in opposite directions, as the opposite directions of rotation of bipolar groups in such latitudes would require.[1] But their velocities, as calculated from Kelvin's formula, should apparently be much greater than the observed solar motions, and a study of the velocity of vortex rings in gases at various pressures is being made to test this point.

As might be expected from the above experiment, a straight, horizontal, flexible vortex, suspended below the surface of water and driven by a pulley at its middle point, turns up to the surface at both of its free ends. Thus any columnar vortex not far below the surface of the photosphere would tend to form a bipolar spot if spinning at a sufficiently high velocity.

A semicircular vortex ring, supported so that the paddles at its two ends come just below the surface of the water, may be used to set up secondary vortices in the air above. To render these visible the space over the water is tightly inclosed in a glass case and filled with smoke.

The circulation observed and photographed in the smoke is inward and downward at high and intermediate levels, then outward along the surface of the water and upward at some distance from the vortex. The horizontal pattern thus produced when a semicircular ring is used (the two paddles at its extremities will serve equally well) closely resembles a side view (in the plane of the ring) of a colored vortex ring rising through water. The structure is decidedly asymmetrical, the

[1]See footnote, page 258.

hoods or arches of smoke on one side of the axis (the side toward which the inner edges of the paddles are moving) contrasting markedly with the stream-lines on the opposite side, which are at right angles to the axis at the center and become more and more convex toward the two ends. Reference has already been made to the apparent presence of similar structure in the hydrogen flocculi (p. 256).

The difference in the form of the stream-lines at different levels can be seen by illuminating the smoke at any desired height above the water with a horizontal slit of sunlight. By placing this slit in a vertical plane, the smoke is shown flowing into the "spots," as in Slocum's photographs of prominences near sun-spots at the limb. Although purely qualitative, the experiments are very interesting and suggestive, and will be developed in a form more closely corresponding with solar conditions.

COMPUTING DIVISION.

The Computing Division has remained throughout the year under the direction of Mr. Seares.

Miss Brayton was appointed to the division on June 1, and for the present will divide her time between the work in stellar spectroscopy and photometry.

Miss Burns joined the division on July 5, and is at present engaged in the work of stellar photometry.

Miss Burwell has continued her work in connection with the investigations in stellar spectroscopy. She has measured 700 spectrograms and has given a large amount of time to the compilation of the data for the radial velocities of 500 stars appearing in *Mount Wilson Contribution* No. 105, besides having measured several plates of nebular spectra for Mr. Pease. She has also given much time to the preparation of the "flash" spectrum results appearing in *Mount Wilson Contribution* No. 95.

Miss Davis joined the division on September 14, and has been associated mainly with the work in stellar spectroscopy. She has measured and reduced 150 spectrograms and has made the least-squares reductions connected with the determination of stellar parallaxes.

Mrs. Fretter has continued with the work of the physical laboratory. Twenty Zeeman photographs have been measured and reduced, and the results from all of the earlier plates have been brought into final form. A number of pressure plates have also been measured, and likewise various interferometer plates. Much measurement and recording was done with the Hartmann microphotometer in the investigation of the Stark effect, and a large number of intensity curves registered with the Koch microphotometer have also been measured.

Until the date of her resignation on March 1, Miss High continued her work in stellar photometry. 18 Selected Area plates, 2 long

exposure North Polar plates, and 228 plates used for the determination of the magnitude scales for the bright polar stars were measured and reduced.

Miss Joyner was appointed to the division on March 1, and since that date has measured and reduced 30 photometric plates of Selected Areas.

Miss McClees has measured and reduced 26 plates of sun-spot spectra and has done a large amount of checking and miscellaneous computing relating to work in photometry and stellar spectroscopy.

Miss Miller, who was appointed on September 14, has assisted in the solar and laboratory investigations of Mr. St. John. Twenty spectrum plates have been measured, and much miscellaneous computing has been done.

Mrs. Monk, who joined the division on October 1, has given her entire time to the work in stellar spectroscopy. Over 250 spectrograms have been measured and reduced. Compilations of star constants and reductions to the sun have also been made by Mrs. Monk.

The time of Miss Richmond has been divided between the work relating to stellar photometry and the measurement of sun-spot spectra. 43 Selected Area plates and 208 photographs for the magnitude scales of bright polar stars were measured and reduced. 17 plates of spot spectra were completely measured, and on several others individual lines were measured for a study of the magnetic field in the vicinity of sun-spot groups. Four test plates for the 100-inch mirror were also measured.

Miss Shumway has continued to serve as recorder and computer in connection with the stellar spectroscopic work. Aside from the regular reductions she has calculated a special table for the transformation of line displacements into radial velocities.

Miss Smith, who resigned on June 1, has continued the routine reductions relating to the spectroheliograph plates. The measurement of the calcium flocculi has been discontinued, but the prominence plates are reduced as formerly. 210 of these were measured, which completes the series to March 21. Prints of 766 spectroheliograms and photoheliograms were made and added to the permanent collection. Miss Smith has also given time to the work in stellar photometry, 41 Selected Area plates having been measured by her. Partial reductions of several of these plates were also made.

Miss Ware has continued her work in connection with the solar and laboratory investigations of Mr. St. John. The laboratory plates include those taken for the investigation of the pole and center effect in the arc and also a certain number of photographs made partly with the vacuum arc and partly under pressure. A number of iron-arc and solar comparison plates have also been measured. The solar plates measured are those made for the determination of the sun's

rotation. Measures on these are for the present confined to the equatorial latitudes.

Miss West was a member of the division from October 1 to July 1, during which time she gave her attention mainly to the work in stellar photometry, and especially to that part relating to the Selected Areas. 26 plates, mostly of the richer fields, were measured and reduced, and much miscellaneous computing was done. Miss West has also transcribed regularly from the original reduction-sheets the results of measures of the sun's general magnetic field used in the investigation of the inclination of the solar magnetic axis.

Miss Wolfe has given the greater part of her time to the final reduction and collection of the results for the Standard Polar Magnitudes. The laborious and exacting compilation of the tables for the final publication of the results has been entirely in her hands. She has further carried out all of the least-squares solutions, about 90 up to date, relating to the investigation of the inclination of the sun's magnetic axis, and has done much miscellaneous computing and checking of results. She has also served as librarian during the absence of Mrs. Longacre.

A number of members of the division have given valuable assistance in connection with the editorial work, among them Miss McClees, Miss Wolfe, and Miss Richmond, and especially Mrs. Longacre and Miss West.

The library, as heretofore, has been in the charge of Mrs. Longacre. The accessions of bound volumes number 215: 66 by purchase, 116 by binding, and 33 by gift. The total number of volumes is now 3,891. The total number of pamphlets and unbound volumes is at present 833.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

The preparation of working drawings for instruments designed in part by members of the staff and in part by the Observatory draftsmen has continued under the direction of Mr. Pease. As in the past few years, most of the time has been devoted to the 100-inch telescope, for which the following complete working drawings have been prepared:

- Declination slow motion.
- Right ascension worm and mounting.
- Apparatus for cutting worm gear.
- Gear for rotating cages.
- Mercury level apparatus.
- Edge ring for top of mirror.
- Newtonian cage.
- Cassegrain and coudé cages.
- Plate-holder.
- Elevator engines for wind screen, cage hoist and platform.
- Counterweight and rope-drive systems for above.
- Dome trucks.
- Cage hoist.
- Right ascension quick motion.

Drawings were also completed for the following instruments:

- Alterations of 60-foot tower telescope and 30-foot spectrograph and 150-foot tower cœlostat and second flat.
- Cassegrain spectrograph (alterations).
- Concave grating, 1-meter focus (alterations).
- 10-inch portrait-lens telescope.
- 13-foot spectroheliograph.
- Laboratory arc.

WORK OF THE OPTICAL SHOP.

In the optical shop, which has remained under the charge of Mr. Ritchey, the work of changing the spherical surface of the 100-inch mirror to a paraboloid has been under way for nearly a year. 80 per cent of the total change necessary has been accomplished in this time, involving 90 days of actual figuring with the large machine. Optical tests have been made each morning after a day's figuring; frequently on account of atmospheric disturbances beyond control, tests have been necessary on more than one morning before figuring could be continued. Two polishing tools of 90° sector form, one of 850 square inches area, the other of 415 square inches area, have been used in this figuring.

Thus far, testing has been done entirely at the center of curvature (about 84 feet from the glass). Now, however, the 60-inch plane mirror has been finished, silvered, and placed in position on a massive iron carriage with straight ways; this allows a motion of the plane mirror for a distance of 66 inches in a straight line at right angles to the axis of the paraboloid. This arrangement permits optical testing to be done both at the center of curvature and at the focus of the paraboloid. The former test is better for determining the figure of the mirror as a whole, while the latter test is invaluable for detecting and correcting zonal errors in the general curvature.

In the work on the 60-inch plane mirror, improved methods of figuring made it highly desirable that the very frequent optical tests might be made without tipping the glass from the horizontal position in which it lies and rotates while being figured. Accordingly, a silvered spherical testing mirror of 14 inches aperture and 16 feet radius of curvature was set up permanently, so that the 60-inch plane could be tested at any time while lying horizontal. On account of the very high foreshortening of the large plane, this test is extremely rigorous for general curvature, *i. e.*, for slight convexity or concavity. Figuring was carried to a very advanced stage by means of this simple and economical test. At a late stage, the 60-inch plane was placed on edge in a vertical position and tested in combination with a 36-inch spherical testing mirror of 50 feet radius of curvature. This showed the general curvature to be sensibly perfect, but revealed some fine narrow zones which were not visible in the former tests on account of the very high foreshortening. As it was not feasible to use the 36-inch spherical mirror for the daily tests while eliminating these fine zones, a new spherical testing mirror of 27 inches aperture and only 135 inches radius of curvature was made, and was used in the manner in which the 14-inch mirror had been used. With the aid of the tests which this mirror afforded, the figuring of the 60-inch plane was readily finished.

During three months in winter, when artificial heat is needed in the optical shop, it is difficult to make the daily tests of the 100-inch mirror satisfactorily. These months have been devoted to the work of

rough-grinding four of the smaller mirrors (two plane, two convex) for the 100-inch telescope.

Considerable time has been spent in experimental work in grinding, polishing, and figuring speculum metal, in the endeavor to apply to this work improved methods of grinding and polishing which have proved highly successful and economical in working glass.

WORK OF THE INSTRUMENT SHOP.

After the completion of the large Koch registering microphotometer last September the chief work of the instrument shop (Mr. Jacomini, chief instrument maker; Mr. Ayers, foreman) included the continuation of the ruling-machine, the 100-inch telescope mounting and dome-drive mechanism, the 10-inch portrait-lens telescope, and three small domes; the machining of the rails for the dome of the 100-inch telescope; the remodeling of the 60-foot tower telescope and 30-foot spectrograph; and the construction of a 13-foot spectroheliograph, a mounting for the 5-foot plane mirror used in testing the 100-inch mirror and various new parts for the 100-inch grinding machine, a 20,000-volt power plant and other apparatus for the Stark effect, a water tank, air-pressure tank and apparatus for vortex experiments, a 4 by 5 plate-measuring machine, and much miscellaneous work, including minor apparatus for the laboratory, additions to the Cassegrain and concave-grating stellar spectrographs, new shop equipment, the installation of safety devices in the shop, instrument repairs, and repairs of power plant and auto-trucks. Some work was also done for the Smithsonian Astrophysical Observatory on Mount Wilson.

Mr. Jacomini has carried the ruling-machine to a point where the actual ruling of gratings may be begun. The experiments of the year have led to some minor modifications in the driving mechanism and the lightening of the grating carriage. Through the courtesy of Dr. Kunz, for which we are greatly indebted, Mr. Jacomini was given an opportunity to study the methods of diamond cutting practiced in the shops of Tiffany and Company, where he gained much valuable information. Recent experiments in cross-ruling are so satisfactory that the ruling of gratings will now be undertaken. Speculum metal plates are being figured for this purpose in the optical shop, and experiments on the use of other alloys have also been made.

The chief addition to shop equipment made during the year is a Rivett precision screw-cutting lathe for small work.

ONE-HUNDRED-INCH TELESCOPE.

Much delay has been experienced at Fore River in the work on the 100-inch telescope mounting, and the first shipment of parts of the instrument, though promised last spring, has just been made. The problem now is to get these heavy pieces (some of them weighing over 9 tons each) to the summit of Mount Wilson before the rainy

season begins. Professor Schwamb, who has continued to act as our superintendent at Fore River, has done everything in his power to hasten the work, but the pressure of other orders has been responsible for the delay. The work on the smaller parts in our own shop has advanced most satisfactorily, and these will be ready to attach to the mounting as soon as it can be assembled on its pier. The driving-clock, which has been completed and tested, is a highly perfected mechanism, and all of the other work is of the same order of excellence.

MOUNTAIN TRANSPORTATION.

Further work on the Mount Wilson road, completed by Mr. Jones last spring, has now given it the width necessary for the transportation of the tube (11 feet in diameter) and other large parts of the 100-inch telescope mounting. During the past spring and summer over 650 tons of steel for the dome have been taken to the summit on the 1-ton and 3-ton auto-trucks. Some of these pieces were 24 feet long, with a maximum weight of 4½ tons.

CONSTRUCTION ON MOUNT WILSON.

The work of grinding the rails on which the 100-inch dome rotates was finished last autumn, and soon after the completion of the road in the spring the erection of the dome was begun by Mr. Jones. As the dome is 100 feet in diameter, the problem of handling the heavy girders was a considerable one, but all difficulties have been overcome, and the dome is now almost completely inclosed. Unless the rains are unusually early, the double sheathing should be finished and the shutter in place this autumn, thus providing safe housing for the mounting as soon as it arrives.

Other work of the year includes the completion of the 60-foot tower telescope, the construction of a storehouse and cottage at the foot of the mountain road, the erection of a small building adjoining the Pasadena office for the 20,000-volt direct-current plant for the Stark effect, and miscellaneous painting and repairs. Some work has also been done on the Smithsonian Observatory buildings.

MOUNT WILSON POWER-PLANT.

Mr. Dowd, who has remained in charge of the power-plant and the cleaning and maintenance of the various telescopes, has also done considerable work of other kinds. This includes the construction and installation of new push-button control switches for quick and slow motions, a motor-driven single-speed reversible controller for the elevator, and a small four-plunger pump for the cœlostat circulating system of the 150-foot tower telescope; a three-speed reversible controller for the motor drive of the 100-inch telescope dome, for use in erection; and a single-speed controller for the power-house. Controllers have also been built for the 5-horsepower mirror-elevator motor and the 3-horsepower clock-wind motor of the 100-inch telescope.

SUMMARY.

The chief results of the year may be summarized as follows:

(1) A tentative working hypothesis of sun-spots, proposed in the annual report for 1912, has been tested by solar observations and laboratory experiments.

(2) As suggested by the hypothesis, the free end of a columnar vortex in water turns up to meet the surface, thus affording a possible explanation of the formation of the second member in a bipolar spot-group.

(3) The tentative conclusion stated in the last annual report, that the vortices of bipolar spot-groups in high and low latitudes rotate in opposite directions, has been confirmed.[1]

(4) It follows from the observed directions of rotation that bipolar groups, if semicircular vortices, should move toward the poles from high latitudes and towards the equator from low latitudes.

(5) The sun-spot measures of Carrington, Dyson, and Maunder show small motions in latitude of the right sign, but their magnitudes appear to be too low.

(6) Kelvin's approximate formula for the velocity of vortex rings has been confirmed in water and is now being tested in air at various pressures in the hope of explaining this apparent discrepancy.

(7) Secondary vortices, produced in smoke above single vortices in water, show a circulation similar to that found by Evershed and St. John in the solar atmosphere above sun-spots.

(8) Right-handed and left-handed smoke vortices, set up by right-handed and left-handed vortices in water, show characteristic asymmetrical stream lines in close agreement with the structure of he hydrogen flocculi above certain bipolar spot-groups.

(9) In other cases these fields of force in the solar atmosphere resemble more closely the lines of force about a bar magnet.

(10) It therefore remains for further work to decide as to the preponderance of the hydrodynamic or the electromagnetic forces which jointly define the structure of the hydrogen flocculi.

(11) Hydrogen flocculi photographed simultaneously with the red and violet edges of *Hα* show remarkable differences in structure.

(12) The characteristic structure and motions of prominences flowing into sun-spots can be closely imitated in vertical sections of the smoke vortices.

(13) Prominences photographed simultaneously in calcium and hydrogen light show interesting differences in structure.

(14) The application of differential methods of observation has rendered possible a marked increase in the accuracy of measurements with the spectrograph and spectroheliograph.

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[1]See footnote on p. 258.

(15) The probable coincidence with prominences of the dark "filaments" photographed on the sun's disk with a 13-foot spectroheliograph is being investigated by various methods.

(16) The various phenomena of the Zeeman effect in sun-spots have been photographed more perfectly than ever before. These include the effects of plane, elliptical, and circular polarization, the resolution of certain lines into at least five components, variations in the separation of the components due to differences in field strength, variations in their relative intensity at different inclinations to the lines of force, and other characteristic effects.

(17) Good progress has been made in the long task of determining the inclination and period of revolution of the sun's magnetic axis.

(18) An application of the Stark effect indicates that the intensity of the sun's general electric field does not exceed 200 volts per centimeter at the hydrogen level.

(19) From a discussion of solar observations it appears that, if the positions of the Fraunhofer lines are influenced by anomalous refraction, the effect must be of the second order. The displacements of the solar lines at the outer edges of spot penumbræ are not appreciably affected by mutual influence, as required by the theory of anomalous dispersion. Of 506 lines, 67 to the violet of stronger lines show the same residuals as the 64 to the red, and weak lines in the broad shading of the strongest lines in the solar spectrum show no systematic changes in displacement as the strong lines are approached.

(20) There appears to be no correspondence between the solar phenomena and the degree of anomalous dispersion shown in the laboratory.

(21) The general displacements of the iron lines in the solar atmosphere seem not to sustain the deductions from the theory.

(22) Contrary to the deductions, the displacements to the red are smaller for solar lines of medium intensity than for the stronger lines.

(23) Many lines exhibiting characteristic pole and pressure effects in the laboratory show displacements to the violet in the sun.

(24) Classified by their displacements in the solar atmosphere, the same iron lines group themselves together as when classified by pressure shift.

(25) The equatorial value of the solar rotation, determined from 26 lines upon 29 plates in the region $\lambda 5018$–$\lambda 5316$, is 1.949 km. per second. For the years 1906 and 1908 the results were 2.064 and 2.053 km., respectively. The progressive change emphasizes the question of the constancy of the solar rotation.

(26) The displacements between the east and west limbs at zero latitude determined by the filar micrometer for three lines of intensity 2 and for the magnesium lines $\lambda 5172$ and $\lambda 5183$ give velocities of 1.962 km. and 2.044 km., respectively. Using the same plates and lines, displacements determined with the Koch microphotometer give 1.955 km. and 2.018 km., respectively.

(27) The equatorial velocities show a progressive increase with intensity of the lines; groups of mean intensities 1.0, 2.0, 3.6, 6.5, and 22 give rotation values of 1.924, 1.933, 1.937, 1.954, and 2.043 km., respectively; 6 enhanced lines of mean intensity 3.2 give 1.928 km., while 5 unenhanced lines of mean intensity 3.6 give 1.937 km. The relative values for lines of increasing intensities, and for enhanced and unenhanced lines, are in agreement with the results of two earlier investigations.

(28) Additional long-exposure photographs of various nebulæ have been obtained during the year.

(29) An extensive report on the interpretation of nebulæ has been prepared by Professor Chamberlin, which will be of great service in planning further work on these objects.

(30) Photographic parallax determinations, having a mean probable error of 0".0055, have been completed for 17 stars.

(31) First-epoch photographs have been secured for 66 stars having proper motions exceeding 0".50, for the purpose of detecting companions.

(32) From the parallactic motions of 55 N stars and 35 O stars the mean parallaxes for these two types have been found to be 0".0022 and 0".005, respectively.

(33) The investigation of standard polar magnitudes has been completed. 617 photographic and 339 photovisual magnitudes are now available. The limits for the two scales are 20.1 and 17.5, respectively.

(34) A detailed comparison of the Harvard and Mount Wilson investigations reveals the source of the discordance for the faint stars, and materially reduces that for the brighter objects.

(35) The work of determining scales of photographic magnitude in the Kapteyn Selected Areas stands as follows: The observational program is three-fourths finished, one-third of the measures are complete, and relative magnitudes are available for 22 areas. Intercomparisons for reduction to the international zero-point have been begun.

(36) Coordinates and diameters have been derived under Professor Kapteyn's direction in Groningen for the stars in 107 of the Selected Areas. The measures are now being reduced to the absolute scale by means of the standard magnitudes whose derivation forms a part of the current photometric program.

(37) A catalogue of the magnitudes and colors of more than a thousand stars in the globular cluster Messier 13 has been completed and a similar catalogue of magnitudes and colors of 300 stars has been made for the open cluster Messier 67.

(38) Nearly 11 per cent of the Messier 13 stars have negative color indices, suggesting that in this direction there is no marked absorption of light in space.

(39) The average color index increases in a remarkable manner toward the center of the cluster, averaging less than +0.6 mag. up to

1′.5 of the center and then increasing to +1.2 mag. in the densest region, where no small or negative color indices are found. This result may indicate that the redder stars are strongly condensed toward the center, that there exists an absorption peculiar to the central part of the cluster, or that some photographic phenomenon such as the Eberhard effect has influenced the results.

(40) Throughout the observed interval of four magnitudes the color index decreases conspicuously with decreasing photovisual brightness. Of the 400 brightest stars, 70 per cent are redder than a normal solar-type star; of the 400 faintest, 85 per cent are bluer than the normal solar-type star.

(41) By statistical methods the parallax of the cluster is found to be less than 0″.0001.

(42) Twenty-three new variable stars have been discovered in the globular cluster Messier 3, bringing the total to 155. Five new variables have been discovered in Messier 13, making a total of 7.

(43) The spectroscopic and photometric orbits of the binary star RX Herculis have been computed and the absolute linear dimensions of the orbit and component stars derived. The mass is peculiarly low for a B-type star.

(44) Computations on the system of Algol (β Persei) show that previous solutions of the photometric orbit are uncertain because of the lack of definite knowledge relative to the amount of darkening at the edge of stellar disks.

(45) The observed darkening toward the limb of the sun is found to conform satisfactorily with the empirical law assumed to represent this phenomenon in the theory of eclipsing binaries.

(46) The photographic range of the eclipsing star TW Andromedæ considerably exceeds the photovisual, indicating that the faint low-density companion is of a redder spectral type.

(47) Computations on the photometric orbits of five eclipsing variables of the second spectral type show that the mean densities are much less than any so far found for the whiter stars.

(48) A special study of the photographic and photovisual light curves of XX Cygni (period 3.2 hours) indicates that its variation is not materially different from that of typical Cepheids. The existence of various types of maxima for this and similar short-period variable stars is definitely established.

(49) The interpretation of Cepheid variation as a phenomenon connected with motion in a binary orbit is found to be untenable.

(50) The radial velocities of 500 stars have been published during the year.

(51) A discussion of these velocities indicates that among the most distant stars the change of velocity with spectral type is much smaller than for the nearer stars.

(52) The radial velocity increases rapidly with the proper motion for the F, G, K, and M stars, and probably for the A and B stars as well. A satisfactory explanation of the change has been found.

(53) The stars of very low absolute luminosity and, probably of small mass, have exceptionally high radial velocities.

(54) Twenty-one spectroscopic binaries have been found during the year, 6 of which show the presence of two spectra on the photographs.

(55) Four stars show radial velocities of +114, +290, −148, and −179 km., respectively.

(56) Twenty stars in the *h* and χ Persei clusters show a common radial velocity of −40 km. The average spectrum of these stars is B 6, and their magnitudes range from 6.3 to 8.6.

(57) The radial velocity of the Andromeda nebula has been measured as −329 km.; and of the bright-line nebula N. G. C. 1068 as +765 km.

(58) Observations of the spectra of bright and faint stars in the Hyades, and of pairs of small proper-motion stars, tend to indicate that the fainter stars intrinsically have spectra which are relatively more intense in the violet portion of the continuous spectrum.

(59) The method of determining the absolute magnitudes of stars, and hence their individual parallaxes, from the relative intensities of certain lines in their spectra has been continued with success throughout the year. A considerable gain in accuracy is to be expected from a revision of the standards of reference for the more distant stars based on parallax observations now in progress.

(60) During the year the spectrum of Nova Geminorum of 1912 has passed from one resembling a planetary nebula into that of a Wolf-Rayet star.

(61) The irregular variable star T Tauri is surrounded by an extensive atmosphere about 4″ in diameter, which shows the bright lines characteristic of Wolf-Rayet spectra. The spectrum of the star proper is about F 5.

(62) The spectra of stars of very low intrinsic brightness show types ranging from K 5 to M b. An exception, however, is the companion to o^2 Eridani, which has the spectrum A 0.

(63) The spectra of 18 stars in the cluster Messier 15 range in type from A 5 to F 5, with one star about G 0.

(64) 840 cobalt and 423 nickel lines in the range $\lambda 3000$–$\lambda 7100$ have been classified in the electric-furnace spectrum with regard to their initial appearance and changes with temperature.

(65) The tube-arc has been found to produce line-dissymmetries varying greatly in magnitude, these being in general toward the red, but in some cases toward the violet. They have been studied with reference to their bearing on changes of wave-length, measurements of the displacements being made with the microphotometer, and have been found to be related to the furnace classification of the lines.

They also correspond closely with the dissymmetries produced by the disruptive spark and with the displacements at the pole of the arc.

(66) Certain resemblances, suggesting a possible indirect relationship, are found between the displacing action of the tube-arc and the pressure effect.

(67) Measures of the Zeeman separation of 363 iron, 186 chromium, and 718 vanadium lines have been made in addition to those previously reported.

(68) Tabulation and reduction to a standard field have been made for 1,132 iron, 1,089 chromium, and 1,361 vanadium lines. For most of these lines there are two or more values in good accordance, though some weak lines have been measured on only one plate.

(69) Between $\lambda 2979$ and $\lambda 6678$, of 1,570 iron arc-lines examined, 286 show displacements to the red and 80 to the violet when the spectrum of light from near the negative pole is compared with that of the center of the arc. At the positive pole the shifts are of the same sign as at the negative, but only about one-fourth as large.

(70) When light is taken only from the center of the arc the current may be changed from 5 amperes to 7 amperes without shifting the *d* lines more than 0.001 A. Lines of group *e* are somewhat more sensitive.

(71) The central section of the Pfund arc, carrying 6 amperes, is practically free from pole effect.

(72) Where the highest precision is sought, the slit should be placed at right angles to the arc axis at its midpoint and the current maintained at a constant value.

(73) Observations upon symmetrical lines with large pressure shifts do not show a general increase of pressure in passing from the center to the negative pole sufficient to account for the observed displacements.

(74) The variation of pole effect with wave-length does not follow the same law as pressure displacements. Therefore, an increase of pressure, localized at the pole and in the core of the arc, does not appear sufficient to explain the displacements. The wave-lengths of the sensitive lines are not affected by a tenfold change in the density of the iron vapor in the furnace, and are independent of a change in the furnace temperature from 2,100° to 2,600° C. Except in a very few special cases, the effect disappears *in vacuo* and in so far appears independent of the fall of potential. Nor does the pole effect appear to be intimately related to the differences in luminosity between the positive and negative poles.

(75) New values of the pressure shift have been obtained for some typical lines in the iron arc spectrum by a method which practically eliminates the pole effect. For groups *a* and *b* the new values accord closely with the best previous work, but for group *d* the new value is about one-half of the old, while for group *e* in the green the shift is nearly zero.

(76) In the green region of the iron arc spectrum the distribution of energy along the axis of the arc has been determined for lines of groups *a* and *e*.

(77) The reflecting power of stellite is distinctly superior to that of speculum metal over the range $\lambda\lambda$ 3200–5800.

(78) The remodeling of the 60-foot tower telescope and 30-foot spectrograph has been finished and a new 13-foot spectroheliograph has been built for use with the telescope. A 20,000 volt direct-current plant and complete laboratory equipment have been provided for the study of the Stark effect. The large Koch registering microphotometer has been completed, and the ruling-machine is now ready for the first trials in ruling gratings. Work on the larger parts of the 100-inch telescope mounting has been nearly finished at Fore River. The driving-clock and many of the smaller parts have been built in our shop. The parabolizing of the 100-inch mirror is about 80 per cent complete and the erection of the 100-foot dome on Mount Wilson is far advanced. The Mount Wilson road has now been widened sufficiently to permit the transportation of the largest parts of the telescope.

NUTRITION LABORATORY.*

FRANCIS G. BENEDICT, DIRECTOR.

With the inception of the Nutrition Laboratory it was essential to construct a building containing specially designed laboratories and to equip these laboratories adequately for a series of researches which would materially extend our knowledge of the nutrition of man. While a considerable amount of scientific apparatus for studying this subject was available at the time of the construction of the Nutrition Laboratory, nevertheless the refinement of methods and particularly the correlation of the measurements of the various physiological factors called for the development of an essentially modern technique. From the beginning this has been considered an important function of the Laboratory.

It was early recognized as a fundamental principle in the work of the Laboratory that experimental evidence must be accumulated, first, with the highest degree of accuracy possible with the present methods of physiological, chemical, and psychological research, and second, in amounts sufficient for drawing conclusions of far-reaching and positive value, unaffected by the personal equation, which may be made the basis for formulating physiological laws. Previously a few experiments have frequently served as a basis for conjectures, but such accumulation of experimental evidence as is planned for the Nutrition Laboratory involves physiological measurements on a scale practically never before attempted.

The amount of time usually available in connection with professorial duties and the transient nature of minor assistants make it necessary for workers in university laboratories to confine themselves for the most part to research problems which are suitable only for intermittent study, and until the foundation of research institutions the advancement of science was in large measure dependent upon this type of research. It is thus clear that the Nutrition Laboratory and similar institutions have a province quite apart from that of academic laboratories; so far as possible, therefore, the researches at this Laboratory have been planned not to interfere with the usual doctorate investigation of the university laboratory. On the other hand, the researches carried out by the Nutrition Laboratory are so extended that the great expense of publication precludes for the most part their appearance in the regular scientific journals, and adequate presentation can usually be obtained only in the form of monographs issued by the Carnegie Institution of Washington.

No little difficulty has been experienced in deciding upon the method of presenting the results. It has been justly claimed that the large

*Situated in Boston, Massachusetts.

mass of evidence produced by this Laboratory lends itself admirably to a modern "statistical" analysis. Unfortunately, in physiological and chemical researches this method of treatment has as yet made but little headway. Numerous conferences with physiologists, both in America and in Europe, have failed to show that the "statistical" method is best adapted at this time for the presentation of the results obtained in the researches of the Nutrition Laboratory. It should be borne in mind, however, that with our methods of recording the protocols and data the material will always be available for subsequent analysis—an analysis that is a definite part of this Laboratory's program in the near future. Until such analysis is possible, therefore, our method of presentation must be for the most part that commonly employed by physiologists and clinicians the classes of scientists especially interested in our researches.

It should furthermore be stated that the Nutrition Laboratory is not—at present at least—so much interested in studying the character of food ingestion as it is in studying the requirement or need for nutriment. The differences between the various proteins, fats, and carbohydrates are, indeed, a part of the regular program of research, but until the demand or need of the body for nutriment is intelligently understood a study of the character of the ingestion of food must be deferred.

LABORATORY CHANGES.

After several years of changing conditions, owing to the confusion caused by the construction of buildings, tunnel, and street in the vicinity, the environmental conditions may be said to have become fairly permanent, and accordingly the grounds have been graded and shrubbery and trees set out in accordance with the designs of a landscape architect. Relatively few fundamental changes have been made inside the building, although it is of interest to note that, even at this early stage in the history of the Laboratory, suitable storage-room for specimens, apparatus, and stock has become a problem.

ADDITIONS TO EQUIPMENT.

The usual additions to the Laboratory equipment of foreign apparatus were seriously interfered with by the war. It was possible, however, through the kindness of Dr. August Krogh, of Copenhagen, to secure a long-delayed shipment of two Blix-Sandström electrically driven kymographs, which were much needed in our work. A 100-liter Tissot spirometer was also obtained through the courtesy of M. Lucien Bull, of the Marey Institute of Paris. On the other hand, there was unusual activity in the construction of apparatus in the Laboratory shop. A detailed description follows:

Bed calorimeter.—The bed calorimeter has been completely reconstructed according to the latest design. It has been used for several tests and shows a high degree of sensitivity and accuracy.

Clinical respiration chamber.—Any type of respiration apparatus requiring the use of nose-breathing or mouth-breathing appliances presents certain difficulties in dealing with pathological cases; a respiration chamber, which may be used in hospitals for studying the respiratory exchange in pathological cases, has therefore long been needed. Such a chamber, based upon our experience with chambers to be used with small animals, has been devised, constructed, and tested during the year with the assistance of Miss E. H. Tompkins. Of the two chambers which have been built, one has been installed in the diabetic ward of the New England Deaconess Hospital for the researches on diabetics; the other chamber has been retained in the Nutrition Laboratory for our regular researches in metabolism. A most critical study of these chambers, including tests of every variety, has demonstrated the comfort of the patients in this apparatus and the accuracy of the results under all experimental conditions.

Infant respiration apparatus.—As a result of our experience with the respiration apparatus for infants, it has been possible to construct a new model which will be employed the coming year for studying the metabolism of infants from one month to two years of age. This, as well as the clinical respiration chambers, is used in connection with the universal respiration apparatus.

Respiration apparatus for small animals.—A complete respiration apparatus for studying the metabolism of small animals, both warm-blooded and cold-blooded, has been constructed and is installed in a building of the New York Zoological Society, where an extensive research on the metabolism of the lower animals is being carried out. This apparatus consists of a small chamber used with the universal respiration apparatus and is of the latest design.

Universal respiration apparatus.—The general use of the universal respiration apparatus, particularly in connection with respiration chambers of varying size, has resulted in the building of two additional apparatus.

Apparatus for the psychological laboratory.—Numerous changes have been made in the psychological laboratory, including particularly the entire reconstruction of the camera for use in photographic registration, for electro-cardiograms, and similar records. A new micrometer head-rest has been constructed for ocular work in general, and a gap commutator for studying the wave-forms of induced currents.

Minor apparatus.—Other products of the Laboratory shop are a photographic apparatus for the reproduction of books, plates, diagrams, etc., a large spirometer which permits the graphic registration of the number and character of the respirations of a subject when walking on the treadmill, and numerous minor alterations in the accessory apparatus used in the walking experiments. In connection with a series of observations on the metabolism of geese during fasting, several metabolism cages for geese were built.

COOPERATING AND VISITING INVESTIGATORS.

The researches on diabetes have been so extensive and so profitable in results that Professor E. P. Joslin has devoted a considerable portion of his time to these studies during the first half of his academic year. This has resulted in an unusual activity, both in the special respiration room at the New England Deaconess Hospital and particularly at the Nutrition Laboratory, where several severe cases of diabetes were studied in the new clinical respiration chamber.

Dr. Fritz Talbot has cooperated in the investigation on infants, with particular reference to the metabolism of the new-born infants, most advantageous arrangements for securing material for study having been made with the Massachusetts General Hospital and the Boston Lying-In Hospital.

Dr. J. H. Means, of the Massachusetts General Hospital, has continued his cooperation with Mr. H. L. Higgins, of the Laboratory staff, in a series of observations on the effect of drugs upon the alveolar air in gaseous metabolism.

Dr. Reginald Fitz, of the Peter Bent Brigham Hospital, devoted a considerable part of his academic year to personal research in the Nutrition Laboratory on the metabolism of cats and other small animals, as shown by the universal respiration apparatus.

Professor Howard T. Karsner, of the Harvard Medical School, cooperated in studying the physiology and the respiration of rabbits in an atmosphere containing a high percentage of oxygen. Following Professor Karsner's removal to the Western Reserve University Medical School, Dr. J. E. Ash, of the Harvard Medical School, has continued the research.

Dr. Francis W. Peabody, of the Peter Bent Brigham Hospital, has spent some time with Mr. H. L. Higgins, of our staff, familiarizing himself with the respiration apparatus, with special reference to the acidosis developed as a result of taking a carbohydrate-free diet.

Dr. Eugene F. DuBois, of the Russell Sage Institute of Pathology, visited the Laboratory during the year, and we are indebted to him for much helpful criticism.

After a leave of absence spent in special research under Professor Otto Folin, of the Harvard Medical School, Dr. T. M. Carpenter has resumed his experimental activities in the Laboratory.

Mr. H. L. Higgins, for a number of years a member of the staff of the Nutrition Laboratory, has resigned to become associated with Dr. John Howland, of the Department of Pediatrics, in the Johns Hopkins Medical School. It would be a difficult task to cite the numerous benefits and the great help that the Laboratory has derived from Mr. Higgins's keen criticism and capacity for painstaking research.

INVESTIGATIONS IN PROGRESS.

Metabolism in diabetes mellitus.—The advent of the unusual and highly promising Allen treatment of diabetes has resulted in the development of a large number of experimental problems which have occupied our attention during the past year. The considerable amount of time that Dr. Joslin has been able to give to this research and the consequent greater activity in this line of investigation have led to the accumulation of much new material The development of the clinical respiration chamber has added greatly to our knowledge of the character of the metabolism in diabetes under various conditions of treatment, and numerous important problems are being profitably studied. The research on diabetes mellitus carried out in connection with the Nutrition Laboratory has now reached such a state of development that arrangements have been made by the New England Deaconess Hospital to maintain diabetic patients in a separate house in which provision has been made for the installation of a complete clinical respiration chamber which will be used for further study.

Metabolism of normal infants.—Arrangements have been made with the Massachusetts Wet Nurse Directory for the use of a special room in their building (within 100 yards of the Nutrition Laboratory) in which researches may be conducted on normal infants, *i.e.*, children of healthy, approved wet nurses; it is thus hoped to extend our observations on normal infants between the ages of one month and two years. This investigation is conducted with the cooperation of Dr. F. B. Talbot.

Metabolism during muscular work.—The research on the metabolism incidental to walking, which was begun by Dr. Murschhauser during 1913–14, has been continued and greatly elaborated by Professor H. Monmouth Smith. The investigation during the last year has included the study of the metabolism of walking at varying speeds and grades. Preliminary to this work, the apparatus was modified by the addition of an extra large spirometer and work-adder attachment, so that not only the respiration-rate but also the total lung ventilation can be graphically recorded on a kymograph. Up to the present time grades as high as 25 per cent and speeds of 80 meters per minute have been studied. The treadmill described in the previous report has been used and continues to give satisfactory results. The simultaneous recording of the oxygen consumption and carbon-dioxide production, the distance walked, the number of steps, the character of the step, the height to which the body is raised both during the entire experiment and at each particular step, the character and rate of respiration and the pulse-rate of a man walking at a rapid rate, either on a level or on varying grades, may now be said to be satisfactorily accomplished. The work with the respiration apparatus is preliminary to a future study, in which the subject and the treadmill will be placed inside of a specially constructed calorimeter.

Pulse-rate during muscular work.—After much experimenting a method has been developed of fastening suitable electrodes to the body of a subject in such way that they will not become loosened during muscular work. This has enabled us to record electro-cardiograms photographically by means of the Bock-Thoma oscillograph and has for the first time given us reliable means for securing continuous pulse-rates during active muscular work. The Bock-Thoma oscillograph, which has been manipulated by Mr. K. H. Brown, of the Laboratory staff, has also been used for obtaining the heart-beat in investigations with geese.

The conversion of carbohydrates to fat in the animal body.—An interesting series of observations, made in 1914, on the metabolism of geese, led to deductions which justified the repetition of certain experiments. An extensive series of observations was therefore made on the surfeit feeding of geese, in which the small respiration apparatus was used for studying a single goose and also the clinical respiration chamber in which six geese were studied simultaneously; the heat-production of the six geese was also directly measured with the bed calorimeter. As a result of these observations, a series of experiments on fasting geese was instituted and carried out by Professor H. Monmouth Smith and Miss Alice Johnson, in June and July of the past year. We hope from these data to establish some relationship between the body-weight, the percentage of nitrogen in the blood, the percentage of nitrogen in the whole body, the percentage of fat in the body, and the basal metabolism as affected by prolonged fasting. The analyses and computations are still being made.

The influence of moderate amounts of alcohol upon psychological processes.—Investigation in this field has been in progress under the direction of Professor W. R. Miles. Five expert male typists, three of whom were "touch" operators, were secured for subjects in an investigation on the effect of small doses of alcohol upon the skilled muscular processes of typewriting. Each subject was provided with the kind and model of typewriter which he used in his regular work as a stenographer. The experimental periods were ordinarily 5 hours in length, the entire series of experiments for each subject lasting 6 to 10 days. It was found that the diversion of spending about one-third of the total test time in taking other measurements helped the subject to keep his attention on the work and dispelled the tendency to fatigue. The cooperation on the part of the subjects was of a high order. The mass of typewriting records secured in these experiments has required a very large amount of time for elaboration.

The amount of alcohol necessary to produce a measurable psychological effect has been variously given by different investigators; in this laboratory from 30 to 50 c.c. of absolute alcohol has been used. Scattered observations concerning the relationship between a dose of this size and the content of the stomach have led us to commence a series of experiments on the problem of a stimulating dose and its

concentration. It is important to know whether or not alcohol can be so diluted that, even though it is taken in relatively large quantities, it produces little or no directly measurable effect.

Data are also being accumulated to throw light upon the question of how long after the ingestion of alcohol measurable psychological effects may be observed. The study of the influence of alcohol on sense thresholds, referred to in the 1914 report, has been somewhat delayed because of the long time necessary for the building of an elaborate visual sensitivity test object by the Nela Park Laboratory. It has also been found desirable for our particular problem to devise better methods and apparatus for studying changes in the sensitivity to electric shock.

Influence of moderate doses of alcohol on metabolism.—Mr. H. L. Higgins, in connection with a study of the respiratory exchange and particularly of the respiratory quotient during alcohol ingestion, has made studies of the rapidity of the absorption of alcohol by normal individuals under varying conditions. The research has been completed from the experimental standpoint and the results are now being prepared for publication.

Use of alcohol in rectal feeding.—As a part of the extended research on the physiological action of ethyl alcohol in man which is being carried out in this Laboratory, Dr. T. M. Carpenter has begun a study of the influence upon the metabolism of the rectal feeding of alcohol with special reference to the time relation and the intensity of the metabolism. It is planned to extend this study to include the combination of alcohol with protein, fat, and carbohydrates.

Normal metabolism of men and women.—No definite series of observations on this subject has been made during the past year, except that in all other researches data for normal subjects have been obtained whenever possible, thus adding materially to our knowledge regarding normal metabolism. It is probable that hereafter this study of normal individuals will be continued only by using fragmentary data incidentally obtained in other studies.

Respiration in oxygen-rich atmospheres.—The adaptation of the universal respiration apparatus to the study of the metabolism of small animals has proved so successful that many experiments of 2 to 8 days have been made with rabbits by Miss M. A. Corson. The effect of variations in the percentage of oxygen was especially studied by Dr. H. T. Karsner. The observations on the respiration with a high percentage of oxygen in the atmosphere have been practically completed and the results are now in press. It is the purpose to continue this investigation further in connection with Dr. J. E. Ash, of the Harvard Medical School, altering the percentage of oxygen somewhat and studying the pathological changes caused thereby. While the greater part of the investigation will be made with rabbits, it is planned to use other animals also, particularly domestic fowl.

Influence of temperature environment upon the metabolism.—Certain preliminary observations regarding the influence of temperature en-

vironment on heat regulation were made in this laboratory a few years ago by Dr. S. Morgulis, and during the past year Dr. Reginald Fitz has contributed somewhat to our earlier fragmentary data. The research is by no means complete, and our chief interest is in outlining further plans of work which shall include a study of the temperature environment not only upon the metabolism of the lower animals but upon that of man.

Basal metabolism after thyroid stimulation.—Except in fevers and in exophthalmic goiter, the known instances in which metabolism is increased in pathological cases are relatively few. The interesting observations of Professor W. B. Cannon, of the Harvard Medical School, have resulted in an important operative procedure for stimulating the thyroid, and Dr. Reginald Fitz has been occupied during the past year in a series of investigations upon the influence of thyroid stimulation upon metabolism. The data secured are being prepared for publication.

Respiration apparatus for large animals or groups of individuals.—With the exception of the large Sondén-Tigerstedt respiration chambers in Stockholm and Helsingfors, in most respiration apparatus only one individual can be studied. An important factor in studying the metabolism of a number of individuals is to secure a proper aliquoting of the ventilating current of air for subsequent analysis. A new device has been perfected for this purpose and the apparatus is now being tested for its practical application in studying the metabolism of large animals and of groups of individuals. The research is still in progress.

The comparative nutrition of the lower animals.—For a more complete understanding of the physiological laws which govern the heat-elimination and heat-production of the body, it is necessary to make experiments with animals in which these factors may be studied. This Laboratory has already undertaken investigations on certain of the lower animals, including cats, rabbits, guinea-pigs, and particularly geese, but it was soon seen that the variations in the skin covering, such as hair, hide, feathers, etc., as well as variations in the shape and composition of the body, particularly as to the proportion of active protoplasmic tissue and inert body-fat, make it desirable to carry out studies upon other than domestic animals. After several conferences, Dr. W. T. Hornaday, director of the New York Zoological Park, has most kindly arranged for an extended study of the basal or resting metabolism of various wild animals. Not only will such a study throw light upon abstract questions, such as heat regulation, but it will have a not inconsiderable bearing upon the feeding of animals in captivity, which at the present time is based entirely upon empirical standards. A special apparatus has been constructed for this research and is installed in a building of the New York Zoological Society.

Translation of foreign literature.—The translation of scientific papers, published in a foreign language and comparatively inaccessible to the research worker, has been continued at the Nutrition Laboratory.

The translations made during the past year have included a number of Russian monographs, also Bohemian and Danish papers, and are now a part of our library. A complete list follows:

I. A. Pashutin:
A study of the metabolism of animals during insufficient feeding and subsequent realimentation. Dissertation, St. Petersburg, 1895, 96+lxiii pp.

O. S. Soltz:
On the anatomical modifications of the bone marrow of animals during acute inanition and subsequent realimentation. Dissertation, Vilna, 1894, 81 pp.

I. I. Protastov:
Metabolism of matter in the organism during the exclusive feeding of sugar. From the Laboratory of General and Experimental Pathology at the Military Medical Academy. Dissertation, St. Petersburg, 1895, 66 pp.

K. A. Hasselbalch:
Respiration experiments with new-born infants. Bibliotek for Laeger, Copenhagen, 1904, 8, R. V., 219 (29 pp.).

F. Mareš:
On the winter sleep of mammals. From the Physiological Institute of the Imperial and Royal Bohemian University in Prague. Sborník Lékařský (Archives Bohêmes de Médecine), 1889, 2, 458.

F. Mareš:
Respirometry and calorimetry of animals. V. Principle of conservation of energy in physiology. From the Physiological Institute of the Imperial and Royal Bohemian University in Prague. Rozpravy České Akademie Císaře Františka Josefa, 1901, 2 (10).

E. Babák:
Respirometry and calorimetry of animals. IV. Heat regulation of the new-born. From the Physiological Institute of the Imperial and Royal Bohemian University in Prague. Rozpravy České Akademie Císaře Františka Josefa, 1901, 2 (10).

PUBLICATIONS.

The following publications have been issued during the year:

(1) Chemical and physiological studies of a man fasting 31 days. Francis G. Benedict Proc. Nat. Acad. Sci., 1, 228 (1915).

A short statement with metabolism chart giving an abstract of the extensive presentation of data in Publication No. 203 of the Carnegie Institution of Washington.

(2) The metabolism of vegetarians as compared with the metabolism of non-vegetarians of like weight and height. Francis G. Benedict and Paul Roth. Journ. Biol. Chem., 20, 231 (1915).

Among the numerous more or less scientifically attested facts concerning the influence of a vegetarian diet are statements relative to an observed increase in endurance and the belief that vegetarians live upon a somewhat lower metabolic plane than do flesh-eaters, who, it is asserted, are unduly stimulated by the protein of food. In the research reported in this paper comparisons were made between a considerable number of vegetarians, 11 men and 11 women, with non-vegetarians of the same sex, height, and weight. From the data for male vegetarians, it appears that there was a slightly less metabolism per kilogram of body-weight and per square meter of body-surface than for the individuals living on a mixed diet, with whom they were compared. This variation was so small, however, that it may be said that no essentially striking difference was apparent between male vegetarians and non-vegetarians. Certainly there was nothing to warrant the belief that male vegetarians subsist upon a materially lower metabolic plane. With the female

vegetarians the slight difference in metabolism shown by the male vegetarians did not appear. We may therefore fairly conclude that living upon a vegetarian diet for a longer or shorter period does not fundamentally alter the basal gaseous metabolism. A study of the respiratory quotients obtained for both classes shows results wholly incompatible with the belief that vegetarians, when in the post-absorptive condition, have a considerably larger proportion of easily combustible carbohydrate material (glycogen) than have non-vegetarians.

(3) The basal caloric output of vegetarians as compared with that of non-vegetarians of like weight and height. Francis G. Benedict and Paul Roth. Proc. Nat. Acad. Sci., 1, 100 (1915).

An abbreviated presentation of the material in the foregoing article.

(4) The metabolism of athletes as compared with normal individuals of similar height and weight. Francis G. Benedict and H. Monmouth Smith. Journ. Biol. Chem., 20, 243 (1915).

Two fundamental conceptions exist with regard to the heat-production of the body. One is that the heat-production is in proportion to the active mass of protoplasmic tissue and the other, a more generally accepted view, is that the heat-production is in proportion to the surface area of the body. An investigation was made upon the metabolism of a number of trained college

Summary of comparison of athletes and non-athletes.

Group No.	Heat-production per 24 hours (computed).			
	Per kilogram of body-weight.		Per square meter of body-surface.	
	Athletes.	Non-athletes.	Athletes.	Non-athletes.
	cal.	*cal.*	*cal.*	*cal.*
I.	22.8	21 3	823	761
II	25 1	22.5	880	789
III.	25 9	23 9	882	811
IV.	25.4	22 3	864	760
V.	25.4	25 4	858	848
VI	25 7	25 5	843	835
VII.	26 0	25 0	841	812
VIII	29.1	24 4	936	790
IX	26 9	26 9	838	830
X	27 7	26 7	863	833
Average	26.0	24 4	863	807

athletes, in whom the proportion of active protoplasmic tissue was undoubtedly much greater than in the body of a normal untrained individual. Differences in surface area were eliminated by making comparisons only between different groups of individuals of like height and weight. Several groups corresponding to various weights and heights were studied, and a final comparison of athletes and non-athletes may best be made by an examination of the summary of all groups given in the table herewith.

It is seen from the general picture of the comparison that the conclusion may justly be drawn that athletes have a somewhat higher metabolism, both per kilogram of body-weight and per square meter of body-surface, than do the non-athletes with whom they may have been compared, and the belief is expressed that the greatly increased proportion of active protoplasmic tissue present in the trained, hardened athlete is alone sufficient to account for the increase in metabolism.

(5) The influence of athletic training upon basal metabolism. Francis G. Benedict and H. Monmouth Smith. Proc. Nat. Acad. Sci., 1, 102 (1915).

An abbreviated presentation of the material in the foregoing article.

(6) A comparison of the basal metabolism of normal men and women. Francis G. Benedict and L. E. Emmes. Journ. Biol. Chem., 20, 253 (1915).

The possibility of a fundamental difference in the gaseous basal metabolism in men and women has been the subject of long study. It is particularly significant in the present-day discussion of energy output, for the composition of the body of a woman is notably different from that of a man of like height and weight, as with the woman there is a larger proportion of subcutaneous fat with a consequent decrease in the proportion of protoplasmic tissue. The research involves the comparison of a large number of subjects, 89 men and 68 women of varying height and age. For stricter comparison the group system was employed, in which the influence of body-surface was eliminated by employing, for purposes of comparison, individuals of like height and weight. A comparison of several groups is given in the accompanying table.

Summary of comparison of normal men and women of like body-weight and height.

Group No.	Heat-production per 24 hours (computed).			
	Per kilogram of body-weight.		Per square meter of body-surface.	
	Men.	Women.	Men.	Women.
	cal.	*cal.*	*cal.*	*cal.*
I...	25.1	22 2	814	726
II...	25.4	22.2	812	714
III..	24.1	25.1	771	796
IV..	26.9	25 0	848	788
V..	27.8	24.9	877	780
VI...	26.3	25.6	818	791
VII...	29.4	24 6	906	752
VIII...	25.7	24.9	792	762
IX..	27.6	26.1	819	780
X...	26.6	26.8	788	784
XI...	26.4	27.4	769	792
Average..	26.5	25.0	819	770

In 8 of the 11 groups, the men show a greater metabolism per kilogram of body-weight than the women. The average data show that the men had a heat-production of 26.5 calories per kilogram per 24 hours as compared with a heat-production of 25.0 calories for the women, approximately a 5 per cent increase. A similar increase is noted with the comparison on the basis of the square meter of body-surface.

Since athletes were carefully excluded from these observations, we deal here only with approximately normal individuals, and in any event individuals of similar height and weight appear in the compared groups. The conclusion is reached that the increased metabolism with man is due to the larger proportion of active protoplasmic tissue.

(7) A comparison of the basal metabolism of normal men and women. Francis G. Benedict and Louis E. Emmes. Proc. Nat. Acad. Sci., 1, 104 (1915).

An abbreviated presentation of the material in the foregoing article.

(8) Factors affecting basal metabolism. Francis G. Benedict. Journ. Biol. Chem., 20, 263 (1915).

As a result of several years' experimentation with normal men and women of different ages, heights, and weights, and the additional data furnished by observations on animals, infants, and particularly a study of a fasting man, general conclusions with regard to the factors affecting basal metabolism are formed. The data all point toward the fact that the mass of protoplasmic tissue is capable of being stimulated to varying degrees of intensity and that this mass of tissue, together with the stimulus, determines the metabolism. That under a large number of conditions the metabolism is roughly proportional to the body-surface is admitted, but that there is any causal relationship between body-surface and metabolism is denied. For practical purposes, the surface area, either as roughly computed by a standard formula or more particularly by the refined method of DuBois, gives an approximate picture of the basal metabolism. The factors affecting basal metabolism are continually in play, and the result is that nothing approximating constancy in relation between surface area and metabolism can be expected in individual cases.

(9) The factors affecting normal basal metabolism. Francis G. Benedict. Proc. Nat. Acad Sci., 1, 105 (1915).

An abbreviated presentation of the material in the foregoing article.

(10) A respiration apparatus for small animals. Francis G. Benedict. Journ. Biol. Chem., 20, 301 (1915).

An adaptation has been made of the universal respiration apparatus to the study of both the oxygen consumption and the carbon-dioxide production of small animals. The apparatus has been tested by control tests, and readily permits a study of the influence of special environmental atmospheres upon the metabolism. The apparatus is at present in use in a study of the influence of high-oxygen atmospheres upon the metabolism of small animals.

(11) Investigations at the Nutrition Laboratory of the Carnegie Institution of Washington, Boston, Massachusetts. Francis G. Benedict. Science, 42, 75 (1915).

A popular presentation of the general methods and results of investigations carried out in the Nutrition Laboratory. The paper is accompanied by a metabolism chart of a man fasting 31 days.

(12) A calorimetric calibration of the Krogh bicycle ergometer. Francis G. Benedict and Louis E. Emmes. Am. Journ. Physiol., 38, 52 (1915).

Of the forms of apparatus used for measuring the severe muscular work of man, that of the bicycle has proved most satisfactory. The ingenious form of bicycle ergometer devised by Dr. August Krogh, of Copenhagen, has been purchased by the Nutrition Laboratory and a series of calibrations made inside the chair calorimeter. These calibrations followed the technique of those made of an earlier and less perfect form of ergometer, the results of which were given in Publication No. 167 of the Carnegie Institution of Washington. The Krogh electric-brake bicycle ergometer was placed inside of the chair calorimeter and rotated from the outside by means of an electric motor. The experiments showed that friction and other factors may be entirely neglected in using the Krogh ergometer. Tests were made at different rates of speed and with different weights on the balance pan.

(13) The energy metabolism of an infant with congenital absence of the cerebral hemispheres. Fritz B. Talbot. Arch. Pediatrics, 32, 452 (1915).

The important relation between the brain and metabolism gave added interest to a study of a human infant with absence of the cerebral hemispheres. Since this infant was deprived of the volitional areas of the brain, its

life was similar to that of a frog in which the cerebral hemispheres had been removed. He therefore did not develop his musculature as would a normal infant of the same age, and as a result his body was made up practically of fat and bones with but a small amount of muscle. The vital functions of this infant were carried on at a low plane, because its existence was purely reflex. The infant showed a very greatly decreased metabolism when compared to normal infants of approximately the same age and weight.

(14) A comparison of methods for determining the respiratory exchange of man. Thorne M. Carpenter. Publication No. 216, Carnegie Institution of Washington (1915).

This publication gives the results of an extensive series of investigations upon the comparative value of a number of methods used for the determination of the respiratory exchange of man. The first part contains a review of the previous work of other investigators and a detailed description of the methods and apparatus used in the research reported, viz: bed respiration calorimeter; the two forms of the Benedict universal respiration apparatus, *i. e.*, tension-equalizer unit and spirometer unit; Zuntz-Geppert, Tissot, and Douglas apparatus; the Haldane gas-analysis apparatus; and minor accessory apparatus. The results of the various comparisons of apparatus follow. The bed respiration calorimeter was made the standard for normal respiratory exchange. Normal, healthy young men were used as subjects and the comparisons of any two apparatus were made on the same day under like conditions of muscular repose and nutrition. The carbon-dioxide elimination, oxygen absorption, respiratory quotient, pulse-rate, respiration-rate, and, when possible, total ventilation of the lungs and volume per respiration were determined.

A series of comparisons of the respiratory exchange obtained with the bed calorimeter and tension-equalizer unit showed agreement in the values for the carbon-dioxide elimination and oxygen absorption, but an agreement of the respiratory quotients was more difficult to obtain. It was believed that this was due more to the difficulty of determining the oxygen consumption in the bed calorimeter than to an actual difference in the character of the respiratory exchange. The two forms of the universal respiration apparatus gave like results. Comparisons of the tension-equalizer unit with the Zuntz-Geppert and the Tissot apparatus, and of the spirometer unit with the Zuntz-Geppert, Tissot, and Douglas apparatus showed that the results of the respiratory exchange obtained with all of these apparatus were entirely comparable. A comparison of the respiratory exchange in mouth-breathing and nose-breathing with the two forms of the universal respiration apparatus and with the Tissot apparatus and in mask-breathing and nose-breathing with the spirometer unit showed that the respiratory exchange is practically identical with the various breathing appliances. A study of the Mueller valves in comparison with the spirometer unit and with the Tissot valves indicated that values obtained with the Mueller valves are reliable when subjects have become accustomed to their use. The addition of dead air-space to the spirometer unit in amounts up to 225 c.c. had no effect upon the respiratory exchange. The omission of the use of the automatic siphon counterpoise on the Tissot spirometer was also without effect upon the respiratory exchange.

Tables of variations and probability curves for the various determinations made are given and discussed for nearly all of the comparisons. The publication concludes with a critical discussion of the sources of error; the advantages and disadvantages of the various apparatus and methods used; breathing appliances; valves; gas-analysis apparatus; and the accuracy and interpretation of the results of experiments on the respiratory exchange of man.

(15) Energy transformations during horizontal walking. Francis G. Benedict and Hans Murschhauser. Publication No. 231, Carnegie Institution of Washington (1915).

The main object of this research was to study the increase in metabolism due to walking on a level at increasing speeds. A complete historical review is given of all previous research in which the gaseous metabolism during horizontal walking has been studied, including a large summary table in which the results of 20 different investigations are recorded and compared on the basis of the movement of 1 kilogram over 1 meter of level path, *i. e.*, 1 horizontal kilogrammeter.

With the universal respiration apparatus and a special type of treadmill designed and constructed in the Nutrition Laboratory by E. H. Metcalf, a study was made in the fall of 1913 and the spring of 1914 of the gaseous metabolism of two subjects during horizontal walking. Determinations were made of the carbon-dioxide production, the oxygen consumption, and the distance walked by the subject; records of the respiration-rate were obtained automatically by a special tambour arrangement; a few records of pulse-rate were secured with the Bock-Thoma oscillograph and the Einthoven string galvanometer; the exact number of steps taken were recorded automatically by a step-counter; and finally, the height to which the body was raised during walking was measured by a work-adder wheel by means of which each upward and downward movement of the body was recorded upon a rotating kymograph drum.

To establish a base-line for comparison with the metabolism during walking, preliminary experiments were made with the subject (1) standing with body relaxed without external support; (2) leaning against a support at the back; (3) leaning on a staff; and (4) standing with muscles tense in the position of "attention." A few experiments were also made with the subject standing and swinging the arms from side to side as in a fast walk, and with the subject sitting and lying.

In the walking experiments the subject walked at a very slow speed, a medium speed, or a very fast speed, and in a few experiments actually ran, thus giving data for comparing the work of forward progression while the subject was walking with that while he was running. A study was also made of the effect on metabolism of fatigue due to long-continued walking.

Usually both the standing experiments and the walking experiments were made during the post-absorptive state, when the subject had no food in the stomach, but the influence of both heavy and light meals upon the metabolism was also studied. In a few experiments the diet was controlled, a special protein, carbohydrate, or fat diet being supplied. In the observations both with and without food the heat per horizontal kilogrammeter was found to be practically independent of the taking of food; an increase in the energy per unit was noted as the speed increased and a considerable less energy per unit when the subject was running as compared with that when he was walking.

The report concludes with an analysis of the mechanics of locomotion.

(16) The effect of certain drugs on the respiration and gaseous metabolism in normal human subjects. Harold L. Higgins and James H. Means. Journ. Pharmacol. and Exp. Therapeutics, 7, 1 (1915).

Observations are reported upon the alveolar carbon-dioxide tension, the respiration-rate, the ventilation of the lungs, and the gaseous exchange, and the results of calculations are given of the volume of dead space in the breathing of normal human subjects following the administration of drugs used in therapeutics, such as atropine, caffeine, camphor, strychnine, morphine, and heroin.

The results obtained are summarized in the following table:

Drug.	Average dose.	Action.				
		Respiratory center.	Bronchial musculature.	Metabolism.	Respiration-rate.	Pulse-rate.
Atropine...	1.0 mg.	None.	Dilation.	Increase.	None.	Fall, then rise.
Caffeine....	0.4 gm.	Stimulation.	Either dilation or none.	Increase.	Increase.	None.
Camphor..	0.1 gm.	None.	Either dilation or none.	Generally slightly increased.	None.	None.
Strychnine.	4.5 mg.	None.	Probably none	None.	None.	None.
Morphine..	16.0 mg.	Either depression or none.	Constriction.[1]	Either slight decrease or none.	Slight increase.[2]	None or decrease.
Heroin	5.0 mg.	Depression.	Constriction.	None.	None.	Slight decrease.

[1]Or none, when the bronchi are already constricted.
[2]This obviously does not apply to large doses of morphine.

(17) Present-day treatment and prognosis in diabetes mellitus. Elliott P. Joslin. Am Journ. Med. Sci., 150, 485 (1915).

In this paper is described the routine treatment of the diabetic patients which have been studied at the Nutrition Laboratory and the New England Deaconess Hospital during the year. A brief summary of the studies in metabolism is also incorporated, special reference being made to the remarkable increase in the respiratory quotient which was observed in those patients undergoing fasting treatment according to the recent publications of Dr. F. M. Allen. The improved prognosis for diabetic patients is illustrated and a comparison made of the 1914–15 cases studied at the Nutrition Laboratory with those of former years.

(18) Carbohydrate utilization in diabetes based upon studies of the respiration, urine, and blood. Elliott P. Joslin. The Harvey Lectures delivered under the auspices of the Harvey Society of New York, 1914–15; also Arch. Internal Med., 16, 693 (1915).

A critical discussion is given in this paper of the character of the evidence available upon which conclusions should be based as to carbohydrate utilization in diabetes. A series of experiments with a large number of cases of severe diabetes is reported, which illustrates the effect of feeding various carbohydrates—oatmeal, potatoes, levulose. In general, it was found that these patients utilized only trifling amounts of carbohydrate. In connection with these studies the interesting observation was made that, following fasting according to the method suggested by Dr. F. M. Allen, severe cases of diabetes showed a rise in the respiratory quotient and, coincidentally with this, a decrease in the acidosis.

(19) The physiology of the new-born infant. Character and amount of the katabolism. Francis G. Benedict and Fritz B. Talbot. Publication No. 233, Carnegie Institution of Washington. (In press.)

Investigations on infants were commenced in the hope of securing information with regard to normal infants prior to an extended pathological study. Strictly normal infants were rarely obtained in the hospital, and it was soon seen that the investigation could more profitably be confined to a study of normal hospital material in the shape of new-born infants. A systematic

research into the metabolism of over 100 new-born infants has resulted in an accumulation of sufficient data for definite conclusions. The infants were for the most part obtained from the Boston Lying-In Hospital and a constant routine was rigidly adhered to in all cases, so that the results are comparable. Several hundred experimental periods were obtained. An analysis of the data for the minimum metabolism periods shows that on the first day of life there are important temperature regulation disturbances which result either in a decreased metabolism, or an increased metabolism when there is an effort on the part of the infant to compensate for the loss of heat. After the second day there is a fair uniformity in the heat-production per square meter of body-surface and a remarkable uniformity per square meter of body-surface per unit of length. This constancy is such as to permit the establishment of a factor which indicates that when the square meter of body-surface, as computed from the body-weight, is divided by the length, the metabolism per unit is 12.65 calories. From a study of the effect of temperature changes on the basal metabolism and the amount of available breast secretion in the first week of life, certain procedures for the conservation of energy and supplemental feeding are suggested.

(20) Psychological effects of alcohol. An experimental investigation of the effects of moderate doses of ethyl alcohol on a related group of neuro-muscular processes in man. Raymond Dodge and Francis G. Benedict. Publication No. 232, Carnegie Institution of Washington. (In press.)

This first publication of results under the program of the Nutrition Laboratory for an exhaustive study with modern techniques of the physiological consequences of the ingestion of moderate doses of ethyl alcohol in man deals with its effects on the neuro-muscular tissues with especial reference to its effects on mental processes. Responses from various levels of the nervous system from the lumbar reflex centers of the cord to the association areas of the cerebral cortex were investigated by techniques which were carefully selected for their objectivity and freedom from arbitrary interference as well as for their accurate measurement of systematically related processes. These approved techniques are carefully described; in connection with the accumulation of normal measurements, they should provide a useful base-line for any future study of experimental variations in the selected processes. The variations from normal of these several measurements, after the ingestion of alcohol doses of 30 c.c. and 45 c.c., respectively, give data for the nature and the comparative incidence of the effects of alcohol on widely different levels of the nervous system.

Electro-cardiograms which were taken synchronously with the other measurements give data for the effect of alcohol on the antagonistic heart-regulating mechanisms in their adjustment to mental and physical activity. The cause of a "relative acceleration" of the heart action under such circumstances was found to be a depression of the inhibiting mechanism.

The results of the measurements not only furnish a solution to many of the outstanding problems of the psycho-physiological effects of alcohol, but they also serve as a basis for interpreting some of the troublesome discrepancies and apparent contradictions in less extensively correlated data, both scientific and unscientific. In conjunction with the pulse data they supply presumptive evidence of the effect of alcohol on organic efficiency. Since the effect of alcohol on motor coordination was found to correlate closely with the average of all the measured effects, the authors conclude that the modification of neural coordination is a central and fundamental consequent to the ingestion of alcohol and suggest that it may properly serve as the most readily accessible indicator of individual susceptibility to alcohol.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. Bauer, Director.

GENERAL SUMMARY.

The adverse circumstances ensuing from the European war, which have proved disastrous to several scientific enterprises of world-wide character, have happily thus far necessitated only a curtailment of the magnetic-survey work of the Department in certain land regions of the globe. The ocean work, as will be seen later, has fortunately suffered no suspension whatsoever.

The chief region in which it was necessary to defer the sending of additional magnetic expeditions was Central Africa. All necessary arrangements had been successfully concluded, before the outbreak of the war, for a second trans-Saharan expedition under the leadership of an experienced magnetician, starting at Tripoli and proceeding to Lake Chad, thence eastward to Egypt or southward to the Atlantic coast. However, just as the expedition was about to start the war broke out, and the countries which had promised the necessary official aid and cooperation considered it best to advise a postponement of the project.

Regarding future scientific aid from nations which have in the past cooperated with the Institution in the execution of the world-tasks assigned to the Department of Terrestrial Magnetism, letters received from eminent investigators make it evident that, even after the cessation of the war, less assistance can be given in the future, owing chiefly to diminished financial resources. Thus there devolve upon us increased reponsibilities if we are to secure a successful conduct of our tasks. It is fortunate that our first general magnetic reconnaissance of the Earth was so nearly completed before the war.

The future magnetic-survey work, therefore, must consist in the filling in of areas where additional data are needed, and assisting certain countries in the completion of surveys undertaken by them which the war conditions not only have interrupted but must indefinitely postpone, unless outside aid is received. Furthermore, magnetic observations must be repeated at a requisite number of points in order to keep proper control of the changes ever going on in the Earth's magnetism.

But there is a second task of equal magnitude and importance to that of the general magnetic survey of the globe, which implies the mapping of the Earth's magnetic field and determining the Earth's magnetic constants—one of fundamental importance in many investigations relating to the physics of the Earth, namely, the study of the

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various *changes* of the Earth's magnetism and the ascertaining of their causes.

Professor Arthur Schuster, in his address on "International Co-operation in Research" before the National Academy of Sciences in April 1913, when referring to international work in terrestrial magnetism, made the following remark:

"Through the magnificent efforts of the Carnegie Institution of Washington, we are at last likely to have a satisfactory magnetic survey of the world, but important as the results obtained by Professor Bauer in the *Carnegie* will prove to be, they will have to be supplemented by systematic observations of the variations of the magnetic forces at a number of fixed stations. Many such stations are in existence, though they are very irregularly distributed over the surface of the Earth."

It may be recalled that Schuster's suggestion had already been included in the original scope of the work of the Department under the heading of "International Observations of the Variations of the Earth's Magnetism" (see Year Book No. 2, 1903, p. 204). While the inauguration of active observational work under this heading had to be deferred, owing to the heavy expense entailed during the first decade of the Department's existence in providing the necessary permanent facilities, such as a non-magnetic ship, office headquarters and research buildings, instrumental equipments, etc., certain preparatory investigations relating to the successful study of the Earth's magnetic variations have been in progress.

But the time is now ripe for the early establishment by the Department of well-equipped observatories, if the requisite financial support is received from the Institution, at which continuous records may be obtained of the variations in the Earth's magnetic, as well as in its electrical, condition. These observatories might appropriately be called *cosmophysical observatories*, in contradistinction to astronomical or astrophysical observatories. For the belief is becoming current more and more that fluctuations in the Earth's magnetism, or in the Earth's electricity, not only contain in them secrets pertaining to physical changes going on within our own planet, but within the universe. Recent studies (see p. 330) indicate, furthermore, that the Earth's magnetic state may respond in a most sensitive manner to changes in solar radiation.

There is need for the early establishment of such cosmophysical observatories, in suitable number and in suitable places, for various reasons. The hope of the Department that the various resolutions passed by international scientific bodies during the past decade and the memorials addressed by noted investigators to their respective countries setting forth the desirability of the establishment of such observatories would bear fruit, has come practically to naught. During this period, the number of new observatories founded is one or two, instead

of ten or more. If efforts, backed by eminent persons and influential scientific assemblies, have been so unsuccessful, even during a period of no war, what may be expected, under the present conditions, during the next decade or two?

When one looks into the geographical distribution of the existing cosmophysical observatories, the first fact, immediately obvious, is that the scientific requirements have been most inadequately fulfilled. Too frequently mere living conveniences, or purely local reasons, have been allowed to govern the selection of a site. For one reason or another, no European country has been able to establish its magnetic observatories on the same broad principles as those which governed the establishment of the magnetic observatories of the United States Coast and Geodetic Survey. Some of the leading European nations, while having within the borders of the home country a greater number of observatories than are scientifically necessary, have established either no observatories in their colonial possessions, or insufficiently support such as exist. Indeed, the conditions permitted at certain of the established observatories are surprising.

About one-half of the 45 existing magnetic observatories are located in Europe; 39 of them are in the Northern Magnetic Hemisphere, hence but 6 in the opposite hemisphere, and at two-thirds of the southern stations the conditions are such that the observatories can not be ranked as first grade.

To prepare for the improvement of existing conditions, as far as may lie within the power of the Department by the means provided, a division, known as the Observatory Division, was created on June 1, 1915, and certain preliminary plans and investigations were undertaken. It is hoped that it may be found possible for the Department in the near future to erect, man, and equip at least two cosmophysical observatories at points in the Southern Hemisphere where they are most needed.

It should be recalled that the adequate solution of all the problems connected with the mapping of the Earth's magnetic state at any given time involves also the adequate accomplishment of the second task here discussed.

MAGNETIC SURVEY OF THE OCEANS.

After the completion of the third cruise of the *Carnegie*, described in the report of last year, she was out of commission for a few months, during which time an observatory was built, just abaft the after dome, for the housing of the instruments used in the measurements of the electrical state of the atmosphere. An additional stateroom was provided for the accommodation of an extra observer. The bottom of the vessel was sheathed with a copper alloy, and a belt, consisting of brass plates, was added to afford some protection against the ice-conditions likely to be encountered on the next cruise.

On March 6, 1915, the *Carnegie* left Brooklyn on her fourth cruise, to extend over a period of about two years, under the command of Mr. J. P. Ault, who had been in charge of the previous cruise. After completing the control-observations in Gardiners Bay, the vessel sailed on March 9, and after a successful trip of 15 days, arrived at Colon, Panama. She proceeded next through the canal, thence to Honolulu, which port was reached on May 21. En route from Balboa to Honolulu during a passage of 39 days, a region of the Pacific was thoroughly covered for which but few magnetic data had been obtained previously.

At the Honolulu Magnetic Observatory an elaborate program was carried out of intercomparisons of all instruments used aboard the *Carnegie*, as well as between the magnetic standards of the Department and those in use at this observatory. During this time the vessel received some overhauling, and on June 29 and July 3 she was swung off Pearl Harbor, at the same place where the observations on the *Galilee* had been made in 1907.

July 3, the *Carnegie* sailed from Honolulu, reaching Dutch Harbor, Alaska, on July 20. On August 5 the vessel started on her long continuous passage of about 8,000 miles to Port Lyttelton, New Zealand, where it is expected she will arrive early in October. By the end of the fiscal year the *Carnegie* will be outfitting to circumnavigate the regions in the southern hemisphere, between the parallels of about 55° to 60° south.

Thus, between March and October of 1915, the *Carnegie* will have sailed from the Atlantic into the Pacific, and from Dutch Harbor, Alaska, to Port Lyttelton, New Zealand, the total distance covered being about 18,000 nautical miles. The aggregate length of the cruises accomplished with this vessel from August 1909 to October 1915 approximates 129,000 nautical miles. Even including all stops, delays, and periods when out of commission, the *Carnegie* has, therefore, averaged a distance per year equal to a complete circumnavigation of the globe along a great circle. The aggregate length of the cruises of both the *Galilee* and the *Carnegie*, 1905–1915, is about 190,000 nautical miles, or 219,000 statute miles, hence nearly 9 times the Earth's circumference.

As has been the case in previous years, the hydrographic establishments engaged in the construction of navigation charts have been kept supplied promptly with the magnetic data of interest to mariners. Usually they are in the possession of the data obtained on the *Carnegie* within 2 or 3 months after the observations have been made. Thus, for example, at the end of August there were transmitted to these hydrographic bureaus magnetic data obtained by the *Carnegie* on the passage from Honolulu to Dutch Harbor, during the previous month, July 3–23. There are letters in our files showing that foreign institutions receive from us magnetic data more promptly than they can get them from vessels and organizations of their own countries.

MAGNETIC SURVEY OF LAND AREAS.

In spite of the adverse conditions prevailing in certain regions on account of the war, the work of the following magnetic expeditions was successfully concluded:

1. A trip of about 2,500 miles, from April to August 1915, through Central Brazil from Rio de Janeiro to Goyaz and down the Araguaya and Tocantins Rivers to Para, under the leadership of Observer D. W. Berky.
2. Interior trips in Southern China and Mongolia, under the direction of Dr. C. K. Edmunds, assisted by Observer F. Brown.
3. Closing of the general magnetic survey of Australia, under the charge of Observer E. Kidson, assisted by Observers Parkinson, Kennedy, and Brown.
4. Trips to the outlying islands of Australasia and to various groups in the West Pacific, by Observer W. C. Parkinson.
5. Completion of interior trips in the Belgian Kongo and Angola, and of a series of magnetic stations along the southwest coast of Africa, by Observer D. M. Wise.

WORK IN WASHINGTON.

RESEARCH BUILDINGS.

The interior installations of the buildings at Washington, D. C., referred to in the report of last year, were practically completed, so that on December 11, 1914, the Trustees, accompanied by Mr. and Mrs. Carnegie and invited guests, could formally inspect the new buildings. The erection of the proposed tower observatory, 80 feet above the ground, for observations in atmospheric electricity, was deferred, pending completion of experiments in an improvised structure on the deck of the main laboratory building.

TERRESTRIAL MAGNETISM.

Volume II of Publication No. 175, bearing the title "Land Magnetic Observations 1911 to 1913, and Reports on Special Researches by L. A. Bauer and J. A. Fleming," was issued by the Institution in August 1915. (See abstract, page 329.) The appearance of this volume was considerably delayed by lack of promptness on the part of some directors of magnetic observatories in transmitting desired data with reference to the intercomparisons of magnetic standards.

Of the special reports in this volume, the most important is the one on pages 211–278, "Results of Comparisons of Magnetic Standards, 1905–1914." It summarizes the results of the various intercomparisons of magnetic standards obtained by the observers of the Department up to the end of 1914, the world over, both at magnetic observatories and in the field among themselves. It is the most complete undertaking of this kind and furnishes valuable data for the correlation of magnetic work by others with that of the Department. It has also served to point out sources of important instrumental errors at certain

observatories. Though the labor involved has been great, the results have proved an adequate recompense. It has been possible to settle on universal or "international magnetic standards" satisfying all requirements, both theoretical and practical, and to transport and reproduce them in remote regions with all necessary accuracy. (Cf. p. 328.)

The manuscript of Volume III (Ocean Magnetic Observations, 1905–1913, and Reports on Special Researches by L. A. Bauer and W. J. Peters) is in good progress, as is also that of Volume IV (Ocean and Land Magnetic Observations, 1914–1916, and Reports on Special Researches by L. A. Bauer, J. P. Ault, and H. W. Fisk).

In addition to the work above mentioned and that shown by the abstracts of papers (pp. 325–342), and the instrumental work described below, a variety of investigations were completed or are in progress. Chief of these may be mentioned the following:

(*a*) Investigations relating to the sources of error in terrestrial-magnetic measurements, and of the causes for changes of instrumental constants, etc., by L. A. Bauer, J. A. Fleming, H. W. Fisk, C. R. Duvall, and W. F. Wallis.
(*b*) Further improvements of ocean instrumental appliances, by L. A. Bauer, W. J. Peters, and J. A. Fleming.
(*c*) Continuation of investigation of the possible relationship between changes of solar radiation and terrestrial magnetism, by L. A. Bauer. (A paper was read before the meeting on Atmospheric Physics, Section B, American Association for the Advancement of Science, San Francisco, August 4, 1915; see abstract, pp. 330, 331.)
(*d*) Preparatory studies of methods for reducing magnetic observations to a common epoch, by L. A. Bauer and H. Bateman.

ATMOSPHERIC ELECTRICITY.

Continued good progress has been made during the year by Dr. W. F. G. Swann, assisted by Dr. S. J. Mauchly, in the theoretical and experimental study of instrumental appliances for measurements in atmospheric electricity. In consequence, it was possible to start out on the present cruise of the *Carnegie* with greatly improved instruments, mounted in a specially constructed deck-house. The installations on the *Carnegie* were completed at Brooklyn and Gardiners Bay under Dr. Swann's direct supervision, and Dr. Mauchly accompanied the *Carnegie* as far as Panama, in order to perfect the operation of the new instruments and to assist in the inauguration of the observational program to be carried out on the cruise by Observer H. F. Johnston.

New methods, or considerable modification of methods of former investigators, have been devised for the measurement of all the atmospheric-electric elements recorded, and special attention has been given to the problem of increasing the speed of the observations and reducing to a minimum all necessary work connected therewith. It has thus become possible for one observer, with a little assistance from a second observer, to make, during a period of about 2.5 hours, 3 measurements of the conductivity, 3 measurements of the ionic content, measure-

ments of the potential-gradient, measurements of the penetrating radiation, measurements of the radioactive content of the atmosphere, and meteorological observations. In the choice of the measurements, and of the way in which they are taken, special attention has been given to arranging matters so that the quantities shall be related to one another in as definite a way as possible.

At Washington studies have been carried out relating to the origin and maintenance of the Earth's negative charge, and to the development of satisfactory instruments for continuously recording the atmospheric-electric elements at fixed stations.

The *Carnegie* observations obtained during the cruise of 1914 have been discussed by Dr. Swann (see abstract, pp. 337-342), and the observations on the current cruise are reduced as soon as possible after being received. For further details, reference must be made to the abstracts.

INSTRUMENTAL WORK.

The instruments, constructed practically entirely in the Department's instrument shop, comprised 2 magnetometers with theodolites, an earth inductor, 3 special galvanometers, and the whole of the instrumental equipment for the atmospheric-electric work on the *Carnegie*, consisting of the apparatus for the measurement of potential-gradient, atmospheric conductivity, ionic numbers, penetrating radiation, and radioactive content of the atmosphere. Furthermore, 5 quartz-fiber electroscopes have been constructed, also 1 conductivity apparatus for land observatory use, several 100-volt batteries of cells, apparatus for the production of high and steady potentials, photographic apparatus for recording ship's motions, and miscellaneous experimental appliances. Progress has also been made on the construction of a new deflector for determining the magnetic declination and the horizontal intensity at sea.

The difficulty experienced in procuring brass and bronze devoid of magnetic impurities has been so serious as to compel the Department to consider the establishment of a small foundry of its own; preliminary arrangements to this end have been made.

DETAILS OF OBSERVATIONAL WORK.

OCEAN WORK.

At the close of the fiscal year 1914 the *Carnegie* lay in Beard's Yacht Basin at Brooklyn, New York. Immediately afterwards the vessel was laid up in ordinary. Plans were prepared for the construction of an observatory just abaft the after dome for the housing of the new instruments used in the atmospheric-electric observations, and for an additional stateroom on the starboard side of the cabin; also for a belt of brass plates as a protection against ice. On January 12 the *Carnegie* was taken over to the Tietjen & Lang Dry Dock Company in Hoboken to have these plans executed, and also to have the vessel's bottom sheathed with a copper alloy for tropical waters. The work was supervised by the firm of Gielow and Orr and by our representative,

Mr. J. P. Ault. These improvements were satisfactorily completed by February 17, on which day the *Carnegie* returned to her berth in Beard's Yacht Basin to be put in commission. While the above work was being done to the vessel, the magnetic instruments were being examined, repaired, or altered in the Department shop as required for the coming cruise, and their constants were redetermined.

After a final inspection of the vessel by the Director and Mr. Peters, the *Carnegie*, on March 6, left Brooklyn for Gardiners Bay, where she was successfully swung on March 7 and 8, preparatory to putting to sea. This was the *Carnegie's* fifth visit to Gardiners Bay for the purpose of swinging ship. The results of these swings, made in 1909, 1910, 1913, 1914, and 1915, confirm the existence of local magnetic disturbance in Gardiners Bay and furnish the desired control on the accuracy of the magnetic work aboard the *Carnegie*. Dr. W. F. G. Swann remained on board to the last moment to complete the installations and tests of the new atmospheric-electric instruments which had been constructed in the Department shop for this cruise, in accordance with his suggestions. In this work he was assisted by Dr. Mauchly and H. F. Johnston.

The *Carnegie* sailed from Gardiners Bay on March 9, 1915, bound for Colon, Panama, the ship's personnel being as follows: J. P. Ault, magnetician and in command of the vessel; Dr. H. M. W. Edmonds, magnetician and surgeon, and second in command; H. F. Johnston, I. A. Luke, and H. E. Sawyer (who joined the vessel at Colon), observers; N. Meisenhelter, meteorological observer and clerk; R. P. Doran, first watch officer; M. G. R. Savary, engineer; second and third watch officers, and 1 mechanic, 8 seamen, 2 cooks, and 2 cabin boys; 23 persons in all. In addition, Dr. S. J. Mauchly remained with the vessel until Panama was reached, to perfect the installation and operation of the newly constructed atmospheric-electric instruments. The passage to Colon was made in 15 days, during which observations of at least one magnetic element and usually of all three were made on every day of the stormy passage. Two deaths from sickness occurred during this passage, namely, A. H. Sorensen, cook, March 11, and W. Stevens, cabin boy, March 24. The ship instruments were compared with the land instruments and a new repeat station was established. Unfortunately the previously occupied stations in the vicinity of Colon are now magnetically affected by the large construction operations. On April 4 the *Carnegie* dragged both anchors in a fierce norther, but finally the anchors held. She was subsequently towed to a pier by the tug *Porto Bello* and the dredge *Caribbean*.

The *Carnegie* was next taken through the canal and then she set sail in the Pacific Ocean on April 12 from Balboa, bound for Honolulu. After 39 days at sea, during which 73 determinations were made of the magnetic declination and 39 each of dip and intensity, including a swing of the ship, the *Carnegie* reported her arrival at Honolulu on May 21. An elaborate scheme of comparisons was carried out between

the ship's magnetic instruments and those of the Honolulu magnetic observatory, operated by the United States Coast and Geodetic Survey, by which a correlation with other magnetic observatories and standards will be effected. Every facility for carrying out these comparisons at the observatory was rendered by the observer-in-charge, Mr. W. W. Merrymon. On June 29 and July 3 the *Carnegie* was swung off Pearl Harbor in about the same locality as that of the *Galilee's* swing of 1907. The results confirm the large differences which had been indicated by the *Galilee* swing, between the values of the magnetic elements at the place of swing and at the observatory, and they also give a means of supplying an additional determination of the constant *A* of the deviation-formula for the *Galilee* at Honolulu. The place of swing can not be surrounded by land stations and hence can not be controlled by land observations. This shows another advantage of a non-magnetic vessel over a vessel with deviations when used in a magnetic survey of the oceans. After all the labor of planning, observing, and swinging ship, and the tedious computations of the deviation-parameters for a vessel having deviations, we are confronted with the fact that hardly one of the few values of *A* which can be observed during a cruise is wholly above the suspicion of being affected by local disturbance. We can only hope that the effect is neutralized in the mean of a number of observations at the different ports available.

On July 20 the *Carnegie* reached Dutch Harbor, having sighted the Bogosloff Islands. The report on the sighting of these islands reads:

"The Bogosloff Islands were seen at a distance of 3 miles at 2 a. m., July 20. There are two islands at present, the eastern one terminating in two high twin peaks ending in sharp points at the top, the western one with one high mountain having a broad top."

On August 5 the vessel started on the long passage of about 8,000 miles to Port Lyttelton, New Zealand, where she arrived on November 2, 1915.

The cruise of the *Carnegie* from Port Lyttelton will be eastward between the fifty-fifth and sixtieth parallels of south latitude. Conditions permitting, stops will be made at South Georgia and Kerguelen Islands, and the vessel will eventually return to Port Lyttelton early in 1916, thus completing a circumnavigation of the globe in these southerly regions. The tracks of the *Erebus* and *Terror* will frequently be crossed, or followed some distances, during this cruise. Crossings will also be made of the tracks of the *Discovery* and the *Gauss*. These tracks for the most part lie in regions where the secular changes of the Earth's magnetism, because of the paucity of the data, are not well determined.

When the *Carnegie* arrived at Dutch Harbor she had already covered about 10,030 nautical miles of her present cruise in 70 days of sailing, at an average of about 143 miles per day. During these 70 days 101 values of the magnetic declination and 56 each of dip and intensity

were observed at sea, besides carrying out an elaborate program of observations in atmospheric electricity. Observations for determination of the amount of atmospheric refraction have been continued, as also the usual meteorological observations.

Table 1 contains a summary of the magnetic declinations and chart corrections observed on the *Carnegie* from Brooklyn to Dutch Harbor, Alaska, during the period March–July 1915. It will be seen that there is a steady improvement in the nautical charts since the data obtained during the past cruises of the *Galilee* and the *Carnegie* became available to hydrographic bureaus. The chart corrections, shown in the table, reach a maximum value of about 1°.5 in the region of the Pacific, between Panama and Honolulu, not previously covered by these vessels. For a general summary of the results in the Pacific Ocean, obtained during the period 1905–1915, see abstract, pages 331–334.

TABLE 1.—*Magnetic declinations and chart corrections observed on the Carnegie from Brooklyn, New York, to Colon, Panama, from Balboa, Canal Zone, to Honolulu, and from Honolulu to Dutch Harbor, Alaska, March–July 1915.*[1]

Observers: J. P. Ault, commanding the *Carnegie*, H. M. W. Edmonds, I. A. Luke, H. F. Johnston, and H. E. Sawyer. *Minus sign indicates west declination, and plus, east declination.*

Date.	Position.		Carnegie.	Chart values.				Chart corrections.			
	Latitude.	Longitude.		Brit.[2]	Ger.[3]	U. S.[4]	C. & G. S.[5]	Brit.	Ger.	U. S.	C. & G. S.
1915	° ′	° ′	°	°	°	°	°	°	°	°	°
Mar. 9	40 23 N	71 48 W	−11.3	−11.6	−11.2	−11.6	.....	+0.3	−0.1	+0.3	......
10	37 48 N	71 45 W	− 9.4	− 9.8	− 9.2	− 9.5	.....	+0.4	−0.2	+0.1	......
10	36 11 N	71 31 W	− 9.3	− 8.5	− 8.3	− 8.6	....	−0.8	−1.0	−0.7	......
11	34 17 N	71 27 W	− 7.5	− 7.2	− 7.1	− 7.5	.....	−0.3	−0.4	0.0	......
11	33 05 N	71 35 W	− 6.8	− 6.3	− 6.3	− 6.7	.....	−0.5	−0.5	−0.1	......
12	31 28 N	71 41 W	− 5.8	− 5.2	− 5.3	− 5.7	.....	−0.6	−0.5	−0.1	......
12	30 09 N	71 59 W	− 4.8	− 4.5	− 4.4	− 4.7	.....	−0.3	−0.4	−0.1	......
13	28 26 N	71 33 W	− 4.2	− 4.0	− 4.0	− 4.2	.....	−0.2	−0.2	0.0	......
13	27 23 N	71 00 W	− 4.1	− 3.9	− 3.7	− 4.0	.....	−0.2	−0.4	−0.1	......
15	24 44 N	70 02 W	− 3.6	− 3.4	− 3.1	− 3.5	−3.5	−0.2	−0.5	−0.1	−0.1
15	23 29 N	69 17 W	− 2.6	− 3.2	− 3.0	− 3.3	−3.3	+0.6	+0.4	+0.7	+0.7
16	23 01 N	69 12 W	− 2.6	− 3 0	− 2.9	− 3.1	−3.1	+0.4	+0.3	+0.5	+0.5
16	22 53 N	68 52 W	− 3.3	− 3.1	− 2.9	− 3.3	−3.3	−0.2	−0.4	0.0	0.0
17	22 36 N	67 27 W	− 4.2	− 3.5	− 3.4	− 3.8	−3.9	−0.7	−0.8	−0.4	−0.3
17	21 50 N	66 37 W	− 4.2	− 3.6	− 3.5	− 4.0	−4.0	−0.6	−0.7	−0.2	−0.2
18	20 57 N	66 39 W	− 4.0	− 3.4	− 3.2	− 3.6	−3.7	−0.6	−0.8	−0.4	−0.3
19	18 43 N	67 47 W	− 3.3	− 2.1	− 1.8	− 2.3	−2.3	−1.2	−1.5	−1.0	−1.0
19	17 46 N	68 53 W	− 1.6	− 1.5	− 0.9	− 1.4	−1.4	−0.1	−0.7	−0.2	−0.2
20	17 04 N	70 03 W	− 0.9	− 0.5	0.0	− 0.7	−0.7	−0.4	−0.9	−0.2	−0.2
20	16 31 N	70 57 W	− 0.2	0.0	+ 0.5	− 0.2	−0.2	−0.2	−0.7	0.0	0.0
21	15 37 N	72 16 W	+ 0.7	+ 0.5	+ 1.2	+ 0.5	+0.5	+0.2	−0.5	+0.2	+0.2

[1]For previous tables, see Terr. Mag., vol. 15, pp. 57–82, 129–144; vol. 16, pp. 133–136; vol 17, pp. 31–32, 97–101, 141–144, 179–180; vol. 18, pp. 63–64, 111–112, 161–162; vol. 19, pp. 38, 126, 204, 234–235.

[2]From British Admiralty Chart No. 2598 for 1912, referred to 1915.

[3]From Reichs-Marine-Amt chart No. 383, Tit. xiv, No. 1, for 1915, and Tit. xiv, No. 2, for 1910, referred to 1915.

[4]From lines of equal magnetic declination for 1915 on U. S. Pilot Chart No. 1400 of North Atlantic, and on U. S. Pilot Chart No. 3500 of the Central American Waters, and from U. S. Hydrographic Office Chart No. 2406 for 1910, referred to 1915.

[5]From United States Isogonic Chart of the West Indies for 1915.

TABLE 1.—*Magnetic declinations and chart corrections observed on the Carnegie from Brooklyn, New York, to Colon, Panama, from Balboa, Canal Zone, to Honolulu, and from Honolulu to Dutch Harbor, Alaska, March–July 1915*—Continued.

Date.	Position.		Carnegie.	Chart values.				Chart corrections.			
	Latitude.	Longitude.		Brit.	Ger.	U. S.	C. & G. S.	Brit.	Ger.	U. S.	C. & G. S.
1915.	° ′	° ′	°	°	°	°	°	°	°	°	°
Mar. 21	14 52 N	73 23 W	+ 1 3	+ 0 9	+ 1 7	+ 1 0	+1.2	+0 4	−0 4	+0 3	+0 1
22	13 53 N	74 50 W	+ 2.0	+ 1 8	+ 2 4	+ 1.7	+1.9	+0 2	−0.4	+0 3	+0 1
23	12 17 N	77 09 W	+ 3 1	+ 2.8	+ 3.4	+ 3.1	+3.1	+0 3	−0.3	0.0	0 0
23	11 44 N	77 58 W	+ 3.8	+ 3.2	+ 3.8	+ 3.4	+3.4	+0 6	0.0	+0.4	+0.4
24	10 51 N	79 12 W	+ 4.2	+ 3.7	+ 4.2	+ 4.0	+3.8	+0.5	0.0	+0.2	+0 4
Apr. 12	8 21 N	79 32 W	+ 4 7	+ 4.4	+ 4.8	+ 4.5	.....	+0.3	−0 1	+0 2	.
13	6 16 N	80 12 W	+ 5.3	+ 4 9	+ 5 4	+ 5.0	...	+0 4	−0 1	+0.3	....
14	5 50 N	80 13 W	+ 5 6	+ 5.0	+ 5.5	+ 5.1	.....	+0 6	+0 1	+0.5	.....
14	5 07 N	80 21 W	+ 5.4	+ 5 1	+ 5.7	+ 5.4	...	+0 3	−0.3	0.0	..
15	4 18 N	80 26 W	+ 5.7	+ 5 3	+ 5.9	+ 5 7	..	+0.4	−0 2	0.0	.....
15	3 36 N	80 47 W	+ 6.0	+ 5 5	+ 6.1	+ 5.9	.....	+0.5	−0 1	+0.1	.....
16	2 52 N	81 28 W	+ 6.5	+ 5 7	+ 6 4	+ 6 2	...	+0 8	+0.1	+0.3	......
16	2 18 N	82 13 W	+ 6.7	+ 5.9	+ 6.6	+ 6.4	...	+0 8	+0 1	+0.3	....
17	2 08 N	83 00 W	+ 6.8	+ 6.2	+ 6 7	+ 6.5	.	+0.6	+0.1	+0 3	...
17	2 10 N	84 25 W	+ 7.2	+ 6.4	+ 6.9	+ 6.6	.	+0 8	+0.3	+0.6	.....
18	2 19 N	85 41 W	+ 7.5	+ 6 6	+ 7 0	+ 6.8	....	+0.9	+0 5	+0.7	....
18	2 22 N	86 45 W	+ 7.6	+ 6.8	+ 7 2	+ 6.9		+0 8	+0.4	+0 7	.....
19	2 11 N	87 40 W	+ 8 0	+ 7 0	+ 7.3	+ 7 0	..	+1 0	+0 7	+1.0	....
19	2 04 N	88 37 W	+ 7 9	+ 7.2	+ 7.4	+ 7.3	...	+0 7	+0 5	+0.6	....
20	2 01 N	89 52 W	+ 8.5	+ 7 3	+ 7.6	+ 7 5	...	+1 2	+0.9	+1.0	.....
20	2 20 N	91 01 W	+ 8.4	+ 7.4	+ 7.6	+ 7 6		+1.0	+0 8	+0.8	....
21	2 53 N	92 12 W	+ 8 5	+ 7.5	+ 7 6	+ 7.6		+1 0	+0.9	+0.9	
21	3 02 N	93 22 W	+ 8 6	+ 7.5	+ 7 6	+ 7 7		+1 1	+1 0	+0 9	
22	3 21 N	95 07 W	+ 8.6	+ 7 6	+ 7.6	+ 7.7		+1.0	+1 0	+0.9	.
22	4 09 N	95 41 W	+ 9.0	+ 7.6	+ 7.6	+ 7.7		+1 4	+1.4	+1 3	..
23	4 41 N	96 00 W	+ 8.6	+ 7.5	+ 7 5	+ 7 6		+1 1	+1 1	+1 0	.
23	5 12 N	96 17 W	+ 8.6	+ 7.5	+ 7.5	+ 7.6	.	+1 1	+1.1	+1.0	.
24	4 35 N	96 04 W	+ 8 7	+ 7 6	+ 7 6	+ 7 6	.	+1.1	+1.1	+1.1	
24	4 22 N	96 06 W	+ 8.7	+ 7 6	+ 7 6	+ 7.7	..	+1.1	+1.1	+1.0	.
25	3 49 N	95 22 W	+ 8.6	+ 7.6	+ 7.6	+ 7.6	.	+1.0	+1.0	+1.0	..
25	3 52 N	95 35 W	+ 8.7	+ 7 6	+ 7.6	+ 7 7	..	+1 1	+1.1	+1.0	
26	4 12 N	96 21 W	+ 8.7	+ 7.7	+ 7.6	+ 7.7		+1.0	+1.1	+1 0	
26	4 13 N	96 26 W	+ 8 9	+ 7.7	+ 7.6	+ 7 7		+1 2	+1 3	+1 2	..
27	5 13 N	98 11 W	+ 8.6	+ 7 7	+ 7.6	+ 7.7	..	+0 9	+1.0	+0.9	
28	6 03 N	98 29 W	+ 8 8	+ 7.7	+ 7 5	+ 7.6		+1 1	+1 3	+1.2	.
29	7 47 N	99 22 W	+ 8.7	+ 7.6	+ 7.4	+ 7.6	.	+1 1	+1.3	+1.1	..
29	8 20 N	99 19 W	+ 9.0	+ 7 6	+ 7.3	+ 7.5	..	+1.4	+1 7	+1.5	
30	8 22 N	99 49 W	+ 8.8	+ 7.7	+ 7.3	+ 7.5	.	+1 1	+1 5	+1.3	
30	8 30 N	100 34 W	+ 8.6	+ 7.7	+ 7.4	+ 7 4		+0 9	+1.2	+1.2	..
May 1	8 29 N	101 34 W	+ 9.1	+ 7.8	+ 7.4	+ 7 5	.	+1.3	+1 7	+1.6	...
1	8 51 N	102 42 W	+ 8.8	+ 7.9	+ 7.4	+ 7.6	..	+0 9	+1.4	+1.2	..
2	9 37 N	104 02 W	+ 9.1	+ 8 1	+ 7 5	+ 7.7	..	+1 0	+1.6	+1.4	.
2	9 55 N	105 05 W	+ 8.9	+ 8.2	+ 7 6	+ 7.8	.	+0 7	+1 3	+1.1	
3	10 12 N	105 58 W	+ 8.9	+ 8 3	+ 7 8	+ 7.9		+0 6	+1 1	+1 0	...
3	10 17 N	107 07 W	+ 8.9	+ 8.5	+ 7.8	+ 8.0	...	+0.4	+1.1	+0 9	....
4	10 14 N	109 06 W	+ 9 3	+ 8.6	+ 7.9	+ 8 1	.	+0 7	+1.4	+1 2	....
4	10 39 N	110 29 W	+ 9.0	+ 8.7	+ 8 0	+ 8.2	.	+0 3	+1.0	+0 8	...
5	10 58 N	111 49 W	+ 9.1	+ 8 8	+ 8.2	+ 8 3		+0 3	+0 9	+0.8	....
5	11 18 N	113 04 W	+ 9.2	+ 8.9	+ 8.4	+ 8.4	..	+0 3	+0.8	+0.8	....
6	11 46 N	114 48 W	+ 9.1	+ 8.9	+ 8 5	+ 8.5	.	+0.2	+0.6	+0.6	......
7	12 35 N	117 31 W	+ 9.3	+ 9.1	+ 8.7	+ 8.6	.	+0 2	+0 6	+0 7	....
7	12 56 N	118 43 W	+ 9 4	+ 9.2	+ 8.7	+ 8.7	.	+0.2	+0 7	+0.7	......
8	13 29 N	120 18 W	+ 9.5	+ 9.3	+ 8.8	+ 8.7	.	+0 2	+0.7	+0 8	......
8	13 47 N	121 26 W	+ 9.8	+ 9.4	+ 8 9	+ 8 7	.	+0.4	+0.9	+1 1	.....
9	14 20 N	123 14 W	+ 9.8	+ 9.5	+ 8.9	+ 8.8	...	+0 3	+0.9	+1.0	....

TABLE 1.—*Magnetic declinations and chart corrections observed on the Carnegie from Brooklyn, New York, to Colon, Panama, from Balboa, Canal Zone, to Honolulu, and from Honolulu to Dutch Harbor, Alaska, March–July 1915*—Concluded.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Latitude.	Longitude.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
May 9	14 57 N	124 49 W	+ 9.8	+ 9.7	+ 9.0	+ 8.8	+0.1	+0.8	+1.0
10	15 37 N	126 50 W	+ 9.9	+ 9.9	+ 9.2	+ 8.9	0.0	+0.7	+1.0
10	16 00 N	127 43 W	+ 9.9	+10.0	+ 9.3	+ 9.0	−0.1	+0.6	+0.9
11	16 40 N	129 33 W	+10.5	+10.2	+ 9.4	+ 9.2	+0.3	+1.1	+1.3
11	17 01 N	130 57 W	+10.1	+10.4	+ 9.5	+ 9.3	−0 3	+0.6	+0.8
12	17 32 N	133 26 W	+10.4	+10.6	+ 9.6	+ 9.5	−0.2	+0.8	+0.9
12	17 34 N	133 42 W	+10.5	+10.6	+ 9.6	+ 9.5	−0.1	+0.9	+1.0
13	18 01 N	135 28 W	+10.6	+10.8	+ 9.7	+ 9.6	−0.2	+0.9	+1.0
13	18 29 N	136 30 W	+10.5	+11.0	+ 9.8	+ 9.7	−0.5	+0.7	+0.8
14	18 51 N	138 07 W	+10.9	+11.1	+ 9.9	+ 9.8	−0.2	+1.0	+1.1
14	19 26 N	139 19 W	+10.9	+11.2	+10.1	+10.1	−0.3	+0.8	+0.8
15	19 39 N	141 14 W	+11.2	+11.3	+10.1	+10.1	−0.1	+1.1	+1.1
15	19 51 N	142 37 W	+10.5	+11.2	+10.1	+10.1	−0.7	+0.4	+0.4
16	19 52 N	143 50 W	+11.0	+11.2	+10.1	+10.1	−0.2	+0.9	+0.9
16	20 01 N	145 12 W	+10.6	+11.1	+10.1	+10.1	−0.5	+0.5	+0.5
17	20 19 N	146 49 W	+10.9	+11.1	+10.1	+10.2	−0.2	+0.8	+0.7
17	20 40 N	148 21 W	+11.1	+11.0	+10.3	+10.3	+0.1	+0.8	+0.8
18	20 49 N	149 58 W	+10.8	+10.9	+10.4	+10.3	−0.1	+0.4	+0.5
18	20 56 N	151 12 W	+10.2	+10.8	+10.4	+10.3	−0.6	−0.2	−0.1
19	21 04 N	153 09 W	+10.7	+10.8	+10.5	+10.3	−0.1	+0.2	+0.4
19	21 11 N	154 09 W	+10.6	+10.8	+10.4	+10.4	−0.2	+0.2	+0.2
20	21 27 N	155 49 W	+10.6	+10.8	+10.5	+10.5	−0.2	+0.1	+0.1
20	21 21 N	157 10 W	+11.0	+10.6	+10.5	+10.4	+0.4	+0.5	+0.6
21	21 14 N	157 40 W	+10.8	+10.6	+10.5	+10.4	+0.2	+0.3	+0.4
June 29 – July 3	21 15 N	157 58 W	+10.7	+10.5	+10.3	+10.4	+0.2	+0.4	+0.3
July 4	22 10 N	158 38 W	+10.6	+10.7	+10.6	+10.6	−0.1	0.0	0.0
4	23 27 N	159 00 W	+11.0	+10.9	+10.9	+11.0	+0.1	+0.1	0.0
5	25 01 N	159 46 W	+11.5	+11.1	+11.2	+11.4	+0.4	+0.3	+0.1
5	26 22 N	160 34 W	+11.6	+11.3	+11.5	+11.8	+0.3	+0.1	−0.2
6	27 32 N	161 02 W	+12.0	+11.5	+11.8	+12.0	+0.5	+0.2	0.0
6	28 30 N	161 08 W	+12.2	+11.6	+12.0	+12.3	+0.6	+0.2	−0.1
7	29 22 N	161 14 W	+12.7	+11.8	+12.2	+12.4	+0.9	+0.5	+0.3
7	30 14 N	161 19 W	+12.8	+11.9	+12.5	+12.5	+0.9	+0.3	+0.3
8	30 52 N	161 21 W	+12.8	+12.0	+12.7	+12.6	+0.8	+0.1	+0.2
8	31 50 N	161 27 W	+12.9	+12.2	+12.9	+12.7	+0.7	0.0	+0.2
9	32 51 N	161 26 W	+13.3	+12.5	+13.2	+12.9	+0.8	+0.1	+0.4
10	36 26 N	161 13 W	+14.5	+13.4	+14.0	+13.6	+1.1	+0.5	+0.9
11	37 17 N	163 10 W	+14.1	+13.2	+13.8	+13.7	+0.9	+0.3	+0.4
11	37 50 N	164 33 W	+13.8	+13.1	+13.7	+13.5	+0.7	+0.1	+0.3
12	38 40 N	166 05 W	+14.2	+13.0	+13.5	+13.2	+1.2	+0.7	+1.0
12	39 30 N	167 28 W	+13.5	+12.9	+13.3	+12.9	+0.6	+0.2	+0.6
13	40 12 N	168 58 W	+12.9	+12.6	+13.0	+12.6	+0.3	−0.1	+0.3
14	41 03 N	170 31 W	+12.4	+12.3	+12.7	+12.2	+0.1	−0.3	+0.2
14	41 18 N	170 28 W	+12.7	+12.4	+12.7	+12.3	+0.3	0.0	+0.4
15	42 12 N	170 20 W	+12.6	+12.5	+12.9	+12.4	+0.1	−0.3	+0.2
15	42 33 N	170 20 W	+12.9	+12.6	+12.9	+12.4	+0.3	0.0	+0.5
16	43 52 N	170 14 W	+12.8	+12.9	+13.1	+12.5	−0.1	−0.3	+0.3
16	44 00 N	170 12 W	+12.8	+13.0	+13.1	+12.6	−0.2	−0.3	+0.2
17	45 06 N	169 59 W	+13.2	+13.2	+13.2	+12.9	0.0	0.0	+0.3
18	49 03 N	169 30 W	+13.8	+13.9	+14.0	+13.8	−0.1	−0.2	0.0
18	50 00 N	169 36 W	+14.0	+14.0	+14.0	+13.9	0.0	0.0	+0.1
18	50 10 N	169 36 W	+14.0	+14.1	+14.1	+14.0	−0.1	−0.1	0.0
19	52 21 N	170 06 W	+14.1	+14.2	+14.1	+14.2	−0.1	0.0	−0.1
19	53 00 N	169 11 W	+14.4	+14.8	+14.8	+14.7	−0.4	−0.4	−0.3
23	53 54 N	166 32 W	+16.5	+16.3	+16.1	+16.5	+0.2	+0.4	0.0

LAND WORK.

AFRICA.

At the beginning of November 1914 Observer D. M. Wise was in the Belgian Kongo, traveling by river steamer up the Sankuru River towards Lusambo, where he arrived on November 6. He then descended the Sankuru, Kassai, and Kongo Rivers to Leopoldville. After a brief stop there, the journey down the river was resumed. From Boma a short trip was made by rail northward as far as Tshela. Returning to Boma, he continued by launch to Banana, and thence by steamer to St. Paul de Loanda, Angola, which he reached on December 24. The magnetic station there was reoccupied, and then, taking advantage of a railway to the interior, he made a trip to Malange, about 300 miles, and occupied 4 stations. Mr. Wise then returned to St. Paul de Loanda and took steamer for Benguela. There again a short trip into the interior was made by rail, covering about 300 miles, and including 6 magnetic stations. After establishing stations at Mossamedes and Tiger Bay, Angola, the return northward was begun. A number of stations were occupied on the coast. On arriving at Libreville, French Kongo, instructions were received to return to Washington. Leaving Libreville on April 25, Mr. Wise arrived at Washington on June 29. He covered an important region in Africa, and established 90 stations. Throughout the trip much kindness and assistance were received from government officials and missionaries.

Observer W. F. Wallis, having completed the series of observations in Libya, Egypt, Abyssinia, and Eritrea (see Report for the year 1914, pp. 313, 314), returned to Tripoli with the purpose of organizing and carrying out, if possible, an expedition southward across the Sahara. In consultation with the governor of Tripolitania, however, it was learned that, owing to the war in Europe, conditions in the interior were somewhat unsettled, and the Italian authorities preferred not to accept the responsibility of permitting a scientific expedition into the interior at that time. On communicating these facts to the Director by cable, Mr. Wallis was instructed to return to Washington. Before leaving Tripoli, however, he reoccupied the magnetic station there. Sailing from Tripoli on November 9, and traveling by way of Naples and New York, Mr. Wallis arrived at Washington on December 8, 1914.

ASIA.

The work accomplished in Asia during the year was that conducted in China by Dr. C. K. Edmunds, chief of party, with the assistance of Observer F. Brown. After completing his portion of the work in Australia Mr. Brown reported to Dr. Edmunds at Canton on January 13. Several weeks were then devoted to comparisons of instruments, both at Canton and at the Hongkong Observatory, and also to preparations for magnetic surveys in Southern China and Mongolia. On March 23

Mr. Brown left Canton for field work in the provinces of Kwangtung, Hunan, Kweichow, Kiangsi, and Fukien. By June 19 he had reached Kweiyang, the capital of Kweichow. After this successful trip Mr. Brown returned to Canton on July 22. A re-intercomparison of instruments was carried out, and then, according to instructions, Mr. Brown proceeded from Shanghai to Peking by rail, making observations en route to fill some gaps in previous work. Dr. Edmunds in the meantime traveled from Shanghai to Peking by sea and by rail, occupying various stations on the way. At Peking, definite arrangements were completed by Dr. Edmunds for the general magnetic survey of Mongolia, on which work both he and Mr. Brown have been engaged since August.

AUSTRALASIA.

At the end of 1914 the general magnetic survey of Australia was practically completed. By the middle of November, all members of Observer E. Kidson's party had arrived at Perth, and during November and the first part of December 1915 they were engaged in intercomparisons of instruments, computations, and other matters connected with closing the work in Australia. Mr. Kidson, chief of party, left Perth on November 28, and after three weeks' leave of absence at Wellington, New Zealand, reported for duty at Washington on February 1.

Observer F. Brown left Perth on December 10 for Canton, to join Dr. Edmunds's party in China. A brief statement regarding his later work will be found under Asia.

Observer W. C. Parkinson left Perth December 26 for Sydney, to undertake an expedition to various island groups in the West Pacific Ocean. Reaching Sydney on January 4, 1915, he reoccupied the magnetic station there, and made final preparations for work in the Pacific islands. Departing from Sydney on January 20, Mr. Parkinson arrived at Nouméa, New Caledonia, five days later, and began there a series of observations covering New Caledonia, New Hebrides, Loyalty Islands, Walpole Island, Banks Island, Norfolk Island, and Lord Howe Island. For transportation, advantage was taken of small steamers, and in one case of a schooner, plying between the islands. Twenty stations were occupied during this trip, though in many cases only partially complete sets of observations were obtained, owing to the limited stay of the vessels in port. Mr. Parkinson returned to Sydney on March 25. His next trip, beginning May 1, carried him through the Fiji, Samoan, Ellice, Gilbert, and Tokelau groups. Through the courtesy of the London Missionary Society, passage on the mission steamer *John Williams* was granted for a large part of the journey. Mr. Parkinson returned to Sydney on August 11, having established 22 stations and secured a series of comparisons of our magnetic standards with those at the Samoa Geophysical Observatory. He next made a trip to the Solomon Islands, where he obtained magnetic observations at 10 stations. On October 13 he proceeded on a trip to Papua.

SOUTH AMERICA.

Field work in Brazil was carried on by Observer D. W. Berky. Leaving Washington on March 5, he arrived at Rio de Janeiro on March 23. Several days were spent in comparing his instruments with those of the magnetic observatory at Vassouras, near Rio de Janeiro. In addition, the Department's station of 1912 at Rio de Janeiro was reoccupied. Preparations were then made for an extensive trip of about 2,500 miles through Central Brazil. Starting from Rio de Janeiro on April 8, the first stage of the journey was by rail to Catalao, then by mule caravan to Goyaz and Leopoldina, the party arriving at the latter place on May 25. Eight magnetic stations were established on the way. Four additional stations were made during a short trip up the Araguaya River in a small boat as far as Registro, which was reached June 8. On the next day the descent of the Araguaya River was begun. Leopoldina was again reached on June 12 and on June 14 the descent was resumed to Concessao, where the party arrived on July 8. Leaving again on July 14, in company with Mr. Luis Antonio do Cruz, a rubber trader, who had a well-manned barge, Alcobaca was reached on August 18, after encountering numerous rapids, shoalings, and portages. Travel was resumed on August 22 by steamer down the Tocantins River to Para, which was reached on August 30. Upon completion of observations at our previous station, Pinheiro, Mr. Berky returned to Washington on September 22. The magnetic elements were determined at 41 stations in all, and valuable geographical data were obtained in a comparatively little known part of Brazil.

MISCELLANEOUS.

Observer E. Kidson, from August to October 31, 1915, was engaged on comparisons of our magnetic standards with those in use at the magnetic observatories in Great Britain.

The Director made a preliminary examination on July 27–28 of the suitability of the region around Pikes Peak, Colorado, for investigating the important question as to change of magnetic elements with altitude and the suitability of Pikes Peak for a mountain magnetic observatory.

DETAILS OF INVESTIGATIONAL WORK.

A general account is given on pages 315–317 of the various researches under this head. A fuller statement respecting some of the chief investigations is contained in the following abstracts of published articles and papers presented before scientific societies, and reports of progress:

Magnetic declinations and chart corrections obtained by the *Carnegie* from Brooklyn, New York, to Colon, Panama, March 1915, and from Balboa, Canal Zone, to Honolulu, Hawaii, March–May 1915. J. P. Ault. Terr. Mag., vol. 20, 69–70 (June 1915).

Magnetic declinations and chart corrections obtained by the *Carnegie* from Honolulu, Hawaii, to Dutch Harbor, Alaska, June–July 1915. J. P. Ault. Terr. Mag., vol. 20, 104 (September 1915).

Summaries of the results of the observations on the *Carnegie* on the present cruise (No. IV) from Brooklyn to Honolulu and thence to Dutch Harbor, Alaska, by the observing staff, J. P. Ault, H. M. W. Edmonds, I. A. Luke, H. F. Johnston, and H. E. Sawyer. (Cf. pp. 320–322.)

On the mean value of a function of spherical polar coordinates round a circle on a sphere. H. Bateman. Terr. Mag. vol. 20, 127–129 (September 1915).

Some years ago von Bezold pointed out that the mean value of the magnetic potential round a parallel of geographical latitude is very nearly equal to a constant multiple of the cosine of the north polar distance. Shortly afterward Adolf Schmidt considered the problem of finding the diameter of the Earth for which the mean value of the magnetic potential round each small circle with the diameter as axis, approximates in the best way to a constant multiple of the cosine of the polar distance from one extremity of the diameter. Schmidt chose as the criterion for obtaining the best approximation the condition that the square of the difference between the two quantities just mentioned, when integrated over the whole Earth, should be a minimum.

While reading Schmidt's paper, in connection with some studies at the Department of Terrestrial Magnetism during the past summer, it occurred to the author that it might be useful to have a simple formula for the mean value of a function round a circle on a sphere. Such a formula can be deduced without much trouble from the formulæ for the transformation of spherical harmonics in a transition from one set of polar coordinates to another. These formulæ have been given by Adolf Schmidt, but the particular theorem here considered is not explicitly mentioned in his paper. A more direct proof of the theorem is obtained in this paper by the use of a certain property of potential functions.

The Earth's Magnetism. L. A. Bauer. Ann. Rep. Smithsonian Institution for 1913. Smithsonian Inst. Pub. 2281, 195–212, 9 pls. (1914). Washington.

The fourth "Halley Lecture," delivered in the schools of the University of Oxford on May 22, 1913; reprinted, after revision by the author and with additional illustrations, from Bedrock, vol. 2, No. 3, October 1913, pp. 273–294. The lecture concerns itself especially with Halley's contributions to terrestrial magnetism, to recent advances relating primarily to the mapping of the Earth's magnetic field at any one time, and to the determination of the secular changes. Among the illustrations are a portrait of Halley, a view of the house occupied by Halley while living at Oxford, and a reduced facsimile reproduction of Halley's first chart of the lines of equal magnetic declination as based on his observations in the Atlantic Ocean during the cruises of the *Paramour Pink*, 1698–1700. In the closing paragraph the belief is expressed that a long step forward will have been taken toward the discovery of the *origin* of the Earth's magnetism when once we have found out the causes of its many and often surprising variations—in brief, that "the keynote of modern investigation in terrestrial magnetism, as in the biological sciences, must surely be the study of the variations and mutations." Of what import the solving of the riddles of the Earth's magnetism might be, is indicated to some extent by Schuster's suggestive remark that "atmospheric electricity and terrestrial magnetism, treated too long as isolated phenomena, may give us hints on hitherto unknown properties of matter."

On the Geographical Variation of the Earth's Magnetism. L. A. Bauer.

This paper, which was read before section A (mathematics) of the American Association for the Advancement of Science at the Philadelphia meeting in December 1914, concerns itself chiefly with the question: Are the geographical variations from the simple type of uniform magnetization parallel to a diameter,

which are shown by the Earth's magnetism, peculiar to the Earth, or are they effects from forces bound up with the direction and speed of rotation of a revolving body? If the latter be true, then the Sun's magnetic field may also be found to be a complex one with its magnetic poles not simply non-coincident with its poles of rotation, but, as in the case of the Earth, not even diametrically opposite. A preliminary analysis of Hale's published observations seemed to indicate that the Sun's field may be as complex as that of the Earth. However, the method of mapping a magnetic field by observing the Zeeman effect in the glowing Sun's vapors is a much more difficult matter than mapping the Earth's field by means of instruments the results of which can be definitely interpreted. Accordingly, it will be well to defer drawing definite conclusions and confine our studies at present mainly to the accumulated data for the Earth's field.

Several years ago the author found that the constant of the Earth's magnetic field proportional or equivalent to the quantity termed "intensity of magnetization," varied in a systematic manner from parallel to parallel, increasing with approach towards the equator. The average value of the constant, expressed in c. g. s. units, for the parallels 60° north and south, was 0.070, whereas for the equator it was 0.082, hence an increase of about 17 per cent on the former value. The conclusion reached was as follows: That if a law be formulated involving a constant term supplemented by one proportional to the square of the sine of the co-latitude, the observed increase from parallel to parallel towards the equator is closely represented. It will be noted that this second term would thus vary in the same way as the radial component of the Earth's centrifugal force. Furthermore, the law stated is similar, as will be recalled, to that of Faye, which represents the variation in the angular velocity, from parallel to parallel, of points on the Sun's surface. The law was found to give a representation of the observed magnetic facts on the Earth to within 1 per cent.

A re-investigation of this interesting matter has been carried out, and it has been found that the constant referred to above shows the systematic increase towards the equator quite generally over the entire Earth. The effect appears to be too large, as judged from laboratory facts, to be accounted for chiefly by some centrifugal action resulting from the Earth's rotation. The matter is, therefore, being examined into from various standpoints. There is some indication that the distribution of land and water plays an important part.

Intercomparisons of the standard instruments at magnetic observatories, 1905–1914. L. A. Bauer and J. A. Fleming. (Presented before the American Physical Society, Washington meeting, April 1915. The data and results on which this paper was based are published in full in Publication No. 175, vol. II, 211–278, Carnegie Institution of Washington. Cf. pp. 321–322.)

For a world-wide magnetic survey, such as that undertaken by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, it is manifestly of the highest importance to know the interrelationship of the various magnetic instruments employed both by the observers of the Carnegie Institution of Washington and of the cooperating organizations. It has been found repeatedly that magnetic instruments, though constructed with the utmost care, may, nevertheless, give values of the magnetic elements which differ, for the various instruments employed, by amounts considerably larger than the purely observational error with any one instrument. The instrumental differences shown, for example, by the very best dip circles, may reach a magnitude 5 to 10 times the observational error. Indeed, cases of dip circles have been found which required a correction, on some carefully determined standard, by an amount equal to the secular change for 10 years and more. Unfortunately, the correction is generally not a constant one, but a function

of the magnetic latitude. Similarly, magnetometers not infrequently, for one reason or another, give values of the magnetic declination, or of the horizontal intensity, erroneous by amounts which must be taken into account for satisfactory work, whether in magnetic surveys or at magnetic observatories.

The sources of these instrumental errors are found to be partly in some imperfection in construction of instrument and partly in imperfect determination of instrumental constants, as for example, of the moment of inertia of the chief magnet, of the distribution coefficients, etc. Numerous examples might readily be cited to show the great care required in the purchase of magnetic instruments, and in the determination and control of the constants, if the aim is to determine the terrestrial-magnetic elements within the requisite and possible accuracy.

The Department of Terrestrial Magnetism has had occasion to design and to construct in its own workshop various types of magnetic instruments to meet the demands of accurate field work on land and at sea. In its latest type of theodolite-magnetometer, there has been added an earth-inductor attachment for the measurement of dip. This one instrument thus suffices for both the astronomical and the magnetic work of land magnetic expeditions. It has been used with success in a difficult land expedition, across the deserts in the northwestern part of Australia, this being the first time that an earth inductor has been utilized for extensive field work. This combined magnetometer and earth inductor, though weighing but 15 pounds (7.2 kg.), has met fully the varied requirements of magnetic work. An accuracy has been reached with this field instrument comparing very favorably with and even at times exceeding that obtained with the standard large types of magnetometers in use at many observatories. Thus the uncertainty in the declination and inclination need not be over 0ʹ.2, and in the horizontal intensity not over 1/5000 part or 0.02 per cent (about 4 units in the fifth decimal C. G. S. for Washington).

It has been found possible by aid of the accumulated data to decide now on "international magnetic standards," designated I. M. S., which apparently yield values of the magnetic elements with an absolute accuracy of about 0ʹ.1 or 0ʹ.2 in declination and inclination, and about 0.01 or 0.02 per cent in the value of the horizontal intensity.

On the basis of these international standards, the corrections of 29 observatory standards, excluding those manifestly defective, range from +1ʹ.8 to −1ʹ.5 in declination (east declination being counted positive), +1ʹ.1 to −1ʹ.1 in inclination (inclination of north end of needle below horizon being regarded as positive), and +0.14 to −0.21 per cent of the value of the horizontal intensity. The average corrections, regardless of sign, are: 0ʹ.5 (declination), 0ʹ.5 (inclination), and 0.06 per cent (horizontal intensity).

The experience gained during the past decade has proved that, when adequate precautions are taken, it is possible to preserve the constancy of magnetic standards, 5 to 10 years, with an accuracy of 0ʹ.2 or less in declination and inclination, and 0.015 per cent or less in horizontal intensity, *i. e.*, within about 3 units of the fifth decimal C. G. S. unit for a magnetic observatory in medium latitudes. Serious discontinuities have been introduced at times in observatory series by lack of requisite precautions, inadequate control of instrumental constants, or changes in constants based on limited experimental data.

General results of the work in atmospheric electricity aboard the *Carnegie*, 1909–1914. L. A. Bauer. Proc. Am. Phil. Soc., vol. 54, No. 216, 14–17 (January–April 1915). Philadelphia.

A paper presented before the annual meeting of the American Philosophical Society at Philadelphia on April 24, 1915. It contains a general account of the progress made by the Department of Terrestrial Magnetism in its work in

atmospheric electricity aboard the *Carnegie* and at the laboratory in Washington. The Department can now enter actively, with increased facilities, upon participation in another world-wide project, namely, the mapping of the Earth's electric field and the study of its variations at fixed points. For a summary of the chief results of the recent work on the *Carnegie*, see Dr. Swann's abstract, pages 337–339.

Researches of the Department of Terrestrial Magnetism (vol. II): Land Magnetic Observations, 1911–1913, and Reports on Special Researches. L. A. Bauer and J. A. Fleming. Quarto. Carnegie Institution of Washington Pub. No. 175 (vol. II). 1915. 278 pages, 13 plates, and 9 text-figures.

The first portion of this publication contains, in continuation of the previous volume of researches (No. 175, vol. I), and, in a similar manner, the results of all magnetic observations made on land by the Department of Terrestrial Magnetism from January 1911 to the end of 1913. In the second portion are given reports on some special researches. New magnetic instruments of light and portable types are described, which were designed, constructed, and used for the field operations subsequent to the work reported on in the first volume. These new instruments include two universal-magnetometer designs, viz, a combined magnetometer and dip circle, and a combined magnetometer and earth inductor. The results of the extensive intercomparisons of instruments at Washington, and in all parts of the world, are given in detail for each instrument.

The stations at which magnetic observations were made between 1911 and 1913 may be summarized as follows: Africa, 207; Asia, 83; Australasia, 284; Europe, 38; North America, 48; South America, 247; islands of the Atlantic Ocean, 16; islands of the Indian Ocean, 14; islands of the Pacific Ocean, 16; Antarctic regions, 30. The total number of stations is thus 983. The table of results (pp. 26–64) gives names of stations, geographic positions, values of the three magnetic elements, dates and local mean times of observations, references to instruments used, and the initials of observers. From about 18 per cent of the results, data for the determination of the secular variation have been obtained.

Extended extracts from the observers' field reports appear on pages 65–128. Following these are concise descriptions of the magnetic stations occupied during the period 1911–1913 (pp. 129–182).

The next section of the volume contains the reports on special researches. The first describes in detail the newly-erected research buildings of the Department at Washington, viz, a main fireproof building containing the Director's headquarters, laboratory, and instrument shop; a one-story non-magnetic building to serve as a testing or standardizing magnetic observatory, and several smaller accessory structures for special investigations in atmospheric electricity and allied subjects. The second report is devoted to L. A. Bauer's inspection trip of 1911, in the course of which he visited various magnetic institutions, and to the observations secured at Manua, Samoa, during the total solar eclipse on April 28, 1911. On plate 10 is a full-size reproduction of the photograph obtained of the eclipse, showing the coronal extensions corresponding to a period of minimum sun-spot activity. The concluding report is concerned with the results of the comparisons of magnetic standards obtained by observers of the Department, during 1905 to 1914, both at magnetic observatories and in the field among themselves. For a statement of the chief results see pages 315–316.

The plates contain illustrations of the research buildings of the Department and of various instruments; also typical views obtained on field expeditions to all parts of the Earth, and finally views of magnetic observatories.

Solar Radiation and Terrestrial Magnetism. L. A. Bauer. Terr. Mag., vol. 20 (Dec. 1915).

This paper was presented at the special meeting on atmospheric physics of section B of the American Association for the Advancement of Science, at San Francisco, August 5, 1915. Doubtless the chief instruments of research from which we may expect definite knowledge respecting certain salient physical characteristics of the highest levels of the atmosphere are the self-recording instruments installed at magnetic observatories for the purpose of registering the countless fluctuations to which the Earth's sensitive magnetic field is continually subject. The paper, in the first paragraphs, shows the rôle which certain terrestrial-magnetic phenomena may play in opening up to us the possible electrical conditions which must obtain in atmospheric regions 100 kilometers and more above the surface, as shown by the researches of Schuster, Birkeland, Stoermer, and Chapman.

Special attention is next paid to the conclusions derived from refined magnetic observations made during periods of increased or decreased solar radiation, as, for example, during times of total solar eclipses, or from a concomitant study of magnetic variations and of variations in the solar constant, as shown by Abbot's observations. The bearing of a certain class of magnetic disturbances, usually recorded only at observatories in the daylight zone, on the question of the magnitude and duration of variations in the solar radiation, is discussed in this connection, and it is indicated how magnetic instruments may effectively supplement other appliances in the detection and measurement of solar radiations of various kinds.

In continuation of the author's investigations, described on pages 323 and 324 of the Annual Report for 1914, an account is then given of the results of a reexamination of the question as to possible changes in the Earth's magnetism which correspond to changes in solar radiation. The solar data used for this purpose are Abbot's values of the solar constant observed at Mount Wilson, California, in 1913, and courteously supplied by him in manuscript in advance of publication. The magnetic data are those furnished by courtesy of the Superintendent of the Coast and Geodetic Survey and apply to the 1913 observations at the stations: Vieques (Porto Rico), Cheltenham (Maryland), Tucson (Arizona), Sitka (Alaska), and Honolulu (Hawaii). Furthermore, there are utilized the 1913 published data for the magnetic observatories at Pola, Potsdam, and Del Ebro.

The provisional results for 1913 confirm those for 1911 and 1912. Thus it is found that a 1 per cent decrease in the solar-constant values for 1913 would correspond to an increase in the "local magnetic constant" of 0.002 per cent of its value.

It is next shown that, as far as may be concluded from the available data for 1913, in about 82 per cent of the cases decreased solar radiation is accompanied by decreased range in the diurnal variation of the Earth's magnetism. A 1 per cent decrease in the solar constant corresponds to a decrease of about 1 per cent in the range of the diurnal magnetic variation.

The proportional magnetic changes associated apparently with a 10 per cent change in the solar constant are of the same general order of magnitude and of the same general sense as those which have occurred during certain total solar eclipses.

The daily non-cyclic changes in the Earth's magnetism, as found on magnetically-quiet days by previous investigators, furnish an additional check on the foregoing results, their quantities harmonizing completely both as regards sign and magnitude with those given here. It is found that on consecutive quiet days the magnetic constant is, on the average, larger on the second day than on the first, the increase being equal to that which would be caused by

an average daily change in the solar constant of 1.5 per cent. Moreover, the reason why the magnetic constant, or the horizontal intensity, is larger, on the average, on the second quiet day, is because, on the average, the solar constant is slightly smaller on the second day than on the first.

General results of the magnetic survey of the Pacific Ocean. L. A. Bauer and W. J. Peters. Terr. Mag., vol. 20, 95–103 (September 1915). Read at the meeting of the American Association for the Advancement of Science, San Francisco, August 4, 1915.

When the magnetic survey of the ocean areas, by the Carnegie Institution of Washington, was begun at San Francisco, ten years ago, little was known of the magnitude of the errors that were supposed to exist in the magnetic charts covering the high seas, and the Pacific Ocean especially, with the exception of the region covered by the voyage of the *Challenger*, was nearly a blank as regards magnetic observations. The first magnetic survey of the Pacific Ocean will be completed by the end of 1916. The cruises of the *Galilee* in this ocean, August 1905 to May 1908, have extended over 61,000 nautical miles; those of the *Carnegie*, between January 1912 and July 1915 (up to her arrival at Dutch Harbor, Alaska), have covered about 36,900 miles, and they will approximate 75,000 miles by the end of 1916. The aggregate length of the tracks followed by both vessels in the Pacific Ocean, 1905 to 1916, will, accordingly, be about 136,000 miles.

During the decade August 1905 to July 1915, in addition to the observations in the Atlantic and Indian oceans, 689 values of the magnetic declination and 578 each of dip and intensity have been observed by the *Galilee* and the *Carnegie* in the Pacific Ocean; or, we may say that magnetic observations have been made in the Pacific at stations averaging about 77 miles apart. The many points of intersection serve to correlate the work of the two vessels and to furnish data for the determination of the secular changes. Besides the magnetic observations made at sea, many others were made on land at each port of call, not only to control the constants of the ship's instruments, but also to obtain data for secular change by reoccupying old stations wherever possible, or to establish stations for future use. Valuable instrumental comparisons were made at the magnetic observatories of Sitka, Honolulu, Zikawei, Tokio, Christchurch, and Apia.

The magnitude of the corrections to the magnetic charts and their distribution is now known in nearly all the oceans. Plate 1 shows the regions of all the largest errors in magnetic declination for the Pacific Ocean. In preparing this plate, the declinations were scaled from charts published in 1898 (U. S. No. 1700), 1905 (British No. 2598 and German XIV, No. 2), and 1912 (British No. 2598), and later editions as they became available during the survey. The corrections are to be added algebraically to the declinations (east declination being considered positive), as scaled from the charts, in order to make them conform to the results from the cruises of the *Galilee* and *Carnegie*. It is not possible to differentiate between the British, German, and American charts without adding more figures and thereby losing the salient features of the diagram. Suffice it to say that usually the corrections to the three charts are about of the same order of magnitude and sign, with the one exception in the group just west of the South American coast. In this group the corrections to the British charts were about 1°.3 numerically smaller than those of the German and American charts, which are the ones shown in this region.

It will be seen that all of the large positive corrections are in an area roughly bounded by the one hundred and fiftieth meridian of west longitude, the North American coast, and an imaginary line drawn from Panama to a point in latitude 50° south, longitude 150° west. The maximum corrections of over +2° are in the south apex of this triangle. It should, however, be stated that the

northern tracks approaching and leaving Sitka are somewhat barren of declination results, owing to the cloudy and foggy conditions that prevail in this region. The largest negative corrections occur in two separate regions. One of these lies between the one hundred and fiftieth meridian of west longitude and the Asiatic coast, the other is between the imaginary diagonal from Panama and the South American coast. The maximum negative errors of about 2°.4 are also found in a high latitude.

The many intersections of the tracks of the two vessels afford important information. If the dates of observations made on intersecting passages are widely separated, the results will furnish data for the calculation of the annual change. If, on the contrary, the elapsed time is sufficiently short the agreement of the results will be some measure of their accuracy.

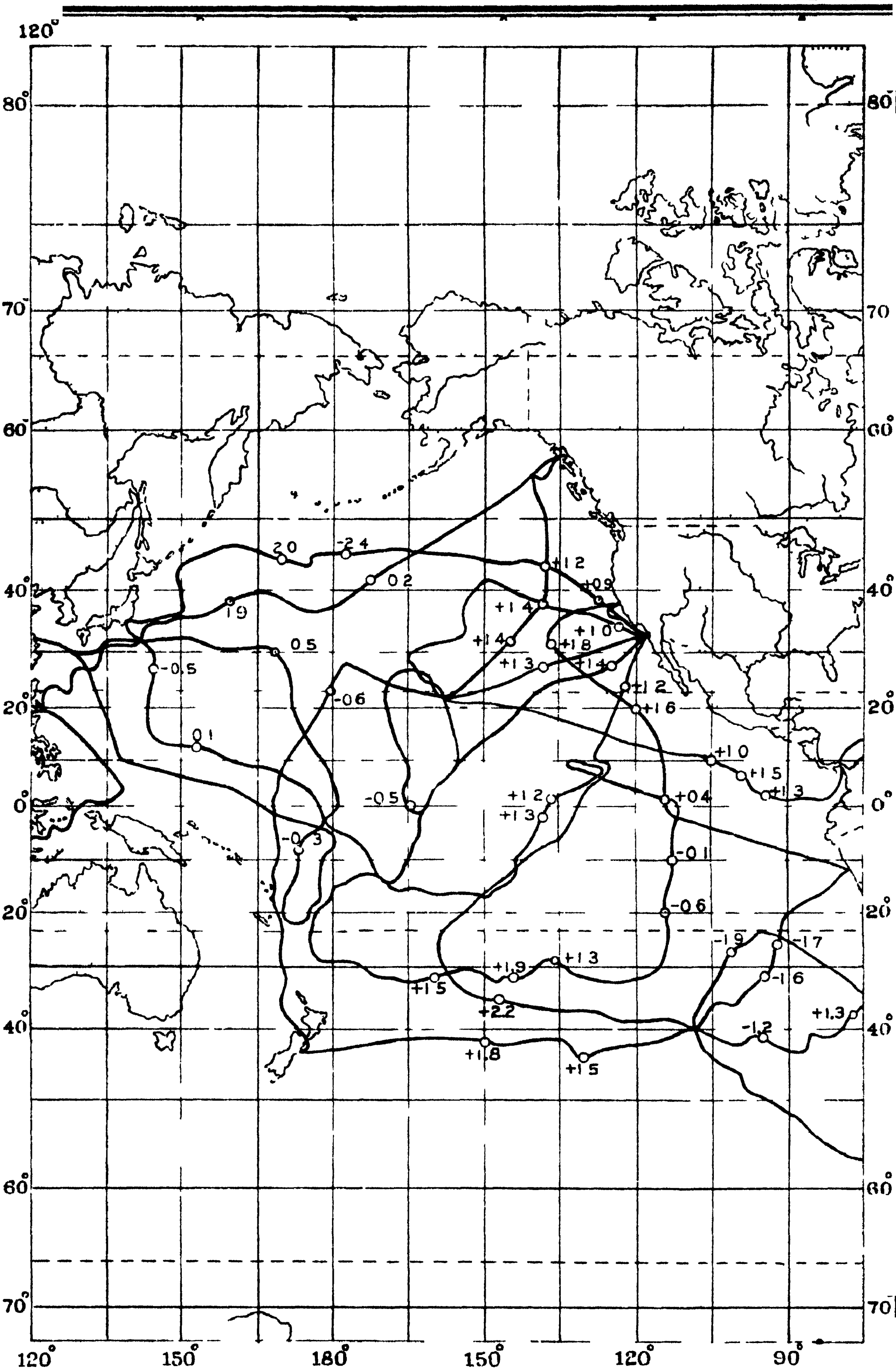
Table 2, of annual changes in magnetic declination for the Pacific Ocean, determined aboard the *Galilee* and the *Carnegie*, shows the comparison with the chart values given on the latest British and United States charts. The annual change is not given on German charts. The annual changes shown in column headed C. I. W. are derived from intersections where observations have been repeated after an interval of more than 4.3 years. It will be seen that, with few exceptions, the annual changes deduced from the observations of the *Galilee* and the *Carnegie* are numerically larger than those given by the charts. The distribution of algebraic signs agrees in a general way with the signs of the chart-corrections shown in plate 1. There is, however, one notable exception: the last value in the table is +0°.10, which falls between the larger positive and negative chart-corrections. The annual change on the island of Tahiti, which lies approximately in latitude 17°.5 south and longitude 149°.5 west, is +0°.07 according to the *Galilee* and *Carnegie* shore observations. The annual change at Suva, Fiji Islands, approximately in latitude

TABLE 2.—*Annual changes in magnetic declination for the Pacific Ocean, determined aboard the Galilee and the Carnegie, and compared with chart values for the period 1906–1913.*

A positive sign indicates a motion of north end of compass needle to east.

Latitude.	Longitude.	Approximate dates.	Average annual change.		
			C. I. W.	British.	U. S.
°	°		°	°	°
31 N.	217 W.	1906.6–1912.3	−0 02	0.00	0.00
26 N.	229 W.	1907 4–1912.3	−0.01	0 00	0.00
19 N.	142 W.	1906.2–1915 4	+0 07	+0.05	+0 04
15 N.	186 W.	1907 8–1912.3	−0.09	*+0.02*	*−0.01*
12 N.	116 W.	1908 3–1915.3	+0.03	+0 06	0.00
6 N.	126 W.	1907.0–1912.6	+0 10	+0.07	*0 00*
1 N.	113 W.	1908 3–1912 6	+0 07	+0 05	0 00
2 S.	182 W.	1906.4–1912.4	−0.04	+0.02	+0.02
12 S.	144 W.	1907.1–1912.7	+0.11	+0.07	*+0 01*
21 S.	190 W.	1907.9–1912.4	−0.01	+0.03	+0.02
26 S.	91 W.	1908.2–1913.0	−0.06	−0.02	*+0.04*
41 S.	105 W.	1908.1–1913.0	+0.10	.. ...	+0.06
Average change, regardless of sign....			0.06	0 04	0.02

18° south, longitude 181°.5 west, is −0°.01. The annual change at Honolulu is practically +0°.04; the geographic position is approximately 21° north and 158° west, about midway between the third and fourth values of the table, but somewhat nearer the positive value.



General Distribution of the Principal Chart Corrections of the Magnetic Declination in the Pacific Ocean The period covered is 1905–1915. The corrections are expressed in degrees and decimals.

The relative accuracy of the *Galilee-Carnegie* results for annual change is different for each determination, since it depends on a different time-interval in each case and also upon a greater or less number of stations more or less differently distributed. If we assume the declination-change with locality to be linear between the stations considered, and the probable error of a single station to be ±0°.15, then the probable errors of the tabulated values of the *Galilee-Carnegie* results would be, in order from top to bottom, respectively, ±°.02, ±°.02, ±°.01, ±°.02, ±°.01, ±°.02, ±°.03, ±°.01, ±°.02, ±°.03, ±°.02, ±°.02.

Table 3, of chart-corrections for dip and horizontal intensity as determined aboard the *Carnegie* in the Pacific Ocean in 1912 and 1915 (to May), shows the necessary corrections to be applied to values scaled from the only charts available, the British Admiralty charts (No. 3598 and No. 3603, published in 1906) and the German Admiralty charts (XIV, 2 *a* and XIV, 2 *b*, published in 1905), to obtain the values given by the *Carnegie*. The dip is considered positive when the north end of the needle is depressed and the horizontal intensity is always positive. The corrections to the British dip chart are −5° or over in three separate regions, and even reach −6°.4. The German chart requires maximum corrections of +4°.0 and +4°.9, and there are occasional disagreements between the two charts of 7° or more.

The corrections for horizontal intensity amount to nearly two units in the second decimal place C. G. S. for one chart, and over one unit in the same decimal place for the other.

TABLE 3.—*Chart corrections for dip and horizontal intensity as determined aboard the Carnegie in the Pacific Ocean in 1912 and 1915 (to May).*

Approximate mean position.		Inclination correction.		Horizontal-intensity correction.		Approximate mean position.		Inclination correction.		Horizontal-intensity correction.	
Lat. N.	Long. W.	Brit.	Ger.	Brit.	Ger.	Lat. S.	Long. W.	Brit.	Ger.	Brit.	Ger.
°	°	°	°	*c. g. s.*	*c. g. s.*	°	°	°	°	*c. g. s.*	*c. g. s.*
29	220	−1.3	+0.8	−.005	−.006	2	236	−1.0	+0.5	−.001	−.002
25	192	−3.1	+1.8	−.011	−.018	11	144	−5.2	+0.4	+.002	+.002
21	237	+0.5	+0.5	−.001	+.002	12	114	−5.8	+1.8	−.002	−.006
18	140	−0.9	−0.2	−.002	−.014	18	187	−1.5	−1.4	−.003	−.002
11	109	−0.5	+2.9	+.006	−.015	28	176	−2.2	−1.8	+.003	−.002
7	227	−0.9	+0.7	−.002	−.005	28	150	−5.0	−0.4	+.004	+.003
5	82	+3.5	+4.0	−.004	−.007	28	127	−6.4	+1.4	+.001	+.010
4	95	+1.0	+4.9	+.006	−.010	29	97	−5.3	+2.0	−.001	+.001
4	128	−1.2	+2.1	+.006	−.010	37	80	−2.0	+1.5	−.002	−.005
2	182	−1.7	+1.4	+.002	− 011	42	104	−5.5	+1.8	−.006	+.008
						54	77	+0.3	+0.9	−.007	−.003

The accuracy of geographic positions at sea is dependent on so many factors that it is quite impossible to define it by exact figures based on any one investigation of numerical results. An examination of some of the three-star determinations of the ship's position made on the *Galilee* indicates that, if the sun or star be favorably situated and the weather and sea conditions fair, the average error to be expected in the determination of the geographic position is less than 2 miles. The error in the control of the ship's run is usually insignificant if the controlling astronomic observations are not more than 6 hours apart. This is usually the case in the *Galilee* and *Carnegie* observations, except in high latitudes, where fog and clouds prevail. Of course there are exceptional times when no astronomic observations are possible for several

days. The geographic positions for the dip and intensity results are then more or less uncertain. In the case of declination-results, however, no such uncertainty can well exist, for the sun or star that serves for the declination observations usually permits at least fairly good determination of position.

Observations for the determination of the amount of atmospheric refraction have been made continuously on the *Galilee* and *Carnegie*, beginning with the *Galilee's* third cruise. Two instruments are now being used on the *Carnegie* in order to vary the conditions. The problem of measuring atmospheric refraction at sea is a difficult one that has not yet been satisfactorily solved. We can only say at present that the results obtained on the *Galilee* and *Carnegie* do not indicate presence of any serious error in the ordinary nautical tables.

The series of observations in atmospheric electricity obtained on the cruises of the *Galilee* and *Carnegie* form one of the most important of recent contributions to observational data. The observations consist in measurements of potential-gradient, conductivity, and radioactive content of the atmosphere, besides the usual meteorological observations. Perhaps the most important result is a confirmation of the somewhat remarkable phenomenon that while the conductivity over the ocean is as large as over land, or larger, the radioactive content is much smaller. The values of the potential-gradient at sea are of the same order of magnitude as those on land.

The recurring series method of seeking hidden periodicities with applications. C. R. Duvall. Read before Philosophical Society of Washington, January 30, 1915.

The following is a brief outline of the theory as advanced by Lagrange and developed by G. N. Armstrong: A generating function, in the form of a general rational proper fraction in x, may be developed into a power series in two ways. In the first, the coefficients satisfy a scale of relation, and in the second the general coefficient is in the form of a sum of products of polynomials by powers. Both processes being uniquely reversible, a general form is determined of a sequence of numbers satisfying a scale of relation. A sum of sine terms may be transformed into a sum of powers, a particular case of a sum of products of polynomials by powers. Hence, any sequence of numbers which may be represented by a sequence of sine terms satisfies a scale of relation, and its general term may be determined, together with the periods, amplitudes, and phases.

Applications (see Annual Report for 1914, p. 319) to magnetic and sun-spot-number data show a striking agreement in the two phenomena of three periods of about 11.4, 22, and 70 years, with some indications of a fourth period of 6 to 8 years. With regard to the 70-year period it is of interest that Professor E. W. Brown has found an apparent common period of about 70 years in the fluctuations in longitude of the Earth, Moon, and Mercury. He suggests that there is a connection between these fluctuations and changes in the Earth's magnetic field, all due, perhaps, to changes in the Sun's magnetic field.

Latest annual values of the magnetic elements at observatories. J. A. Fleming and W. F. Wallis. Terr. Mag., vol. 20, 131–135 (September 1915).

A compilation of the most recent annual values of the magnetic elements at observatories distributed over the Earth.

The atmospheric-electric work of the Department of Terrestrial Magnetism. W. F. G. Swann. Read before the Philosophical Society of Washington, January 30, 1915.

The paper comprised a review of the developments made at the Department of Terrestrial Magnetism in the instrumental methods of measurement during the year 1913–14, and a discussion of the results obtained up to date, chiefly in connection with the ocean work.

Among the greatest difficulties to be contended with in work at sea is that of securing good insulation. It has consequently been arranged that in all measurements the results are, as far as possible, independent of this requirement. In the measurement of potential-gradient, very serious errors may arise because of faulty insulation, if the ordinary method involving the use of some form of collector is employed. For this and other reasons, during the third cruise of the *Carnegie*, a form of instrument was employed of the type described by the author in a previous paper.[1] This instrument has lately been modified somewhat in design in order to render it more convenient for manipulation under ship conditions, and as at present used on the fourth cruise of the *Carnegie*, it consists of a brass tube fixed at one end to an axle so that it can rotate in a plane containing the fore-and-aft line of the ship. The axle is fitted to the stern rail of the ship, and the free end of the brass tube carries a gauze disk made somewhat in the form of a parasol. The handle by which the rotation is brought about is insulated from the axle, and the latter is itself insulated from earth by causing it to work in brass tubes fixed into their supports with sulphur insulation. The axle is connected by a thin wire to a Wulf bifilar electroscope, the wire and the axle being in the same line. It is arranged that when the brass tube is vertical and the parasol attachment is downward, the electroscope system is earthed. On rotating the tube to some other position fixed by a stop, a deflection is obtained in the electroscope which is proportional to the potential-gradient. Insulation difficulties are entirely overcome, since the leak occurring during the turning of the handle from one position to the other is negligible. The sensitivity is considerable, and it is easy to arrange that deflections amounting to the whole scale-length are obtained for the normal value of the potential-gradient.

In addition to the potential-gradient, the atmospheric-electric observations comprise measurements of the ionic content and conductivity for positive and negative ions, the radioactive content of the atmosphere, and the number of ions produced per cubic centimeter per second in a closed vessel. A small observatory has been erected on the *Carnegie*, abaft the after dome, and it has been arranged that, as far as possible, the instruments are permanently mounted in this observatory, only those portions projecting through the roof which have to be exposed to the air. In this way, since the inside of the observatory is always above the dew-point for the air outside, a great deal of trouble arising from deposition of dew on the apparatus is avoided. The ionic content is measured with the instrument described by the author in a former paper.[2] The whole instrument is supported on a gimbal, and only the open end of the receiving tube projects above the observatory. The conductivity is measured on the general principles of the method devised by Gerdien, but several modifications have been made in the apparatus. The concentric cylinders between which the air passes are mounted on the roof of the observatory, so that they can be rotated in such a way that the open end of the apparatus faces the wind. The electroscope system hangs from a gimbal inside the house, and the fan is driven by a small electric motor. This latter arrangement makes it possible to obtain a much greater rate of flow of air, with the result that higher potentials can be applied to the central system and greater sensitivity attained. It is further arranged that the air is blown down into the observatory, whence it departs slowly through the windows. There is thus less chance that air which had been robbed of its conductivity by the apparatus will reenter the apparatus again.

The Elster and Geitel stretched-wire method for measuring the radioactive content of the atmosphere has several disadvantages which have been discussed in a former paper.[3] Even when the instrumental uncertainties have

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[1]Terr. Mag., vol. 19, pp. 182–185, September 1914. [2]*Ibid.*, pp. 171–175. [3]*Ibid.*, pp. 176–182.

been overcome there remains the fact that the "activity" as measured depends on the specific velocities of the radioactive carriers as well as on the true radioactive content of the air. For this reason a new method has been developed by the author. The general principle involved in this method has been used in one form or another by other investigators. It consists in drawing air between two concentric cylinders, the central one of which is charged negatively to such a high potential that it catches all of the active carriers entering the concentric cylinders. The saturation current produced in an ionization chamber by the active deposit collected in a given time, combined with a knowledge of the air-flow during the collection of the deposit, makes it possible to estimate the amount of active material per cubic meter of air, if one assume a knowledge of the nature of the deposit, which can be obtained from the form of the decay curve.

The collecting apparatus, as at present employed, consists of a copper cylinder 25 inches long and 12 inches in diameter, with an anemometer at one end and a fan at the other. The central system consists of an insulated wooden cylinder 4.7 inches long, supported by a rod passing through its axis and insulated from it by sulphur. The surface of the wooden cylinder is covered with copper foil held on by rubber bands, and it is on this foil that the deposit is collected. Earthed metal caps attached to the central rod fit over the top and bottom of the central cylinder without touching it, and insure that the deposit of the active material is confined to the copper foil.

A large air-current is necessary if a large amount of deposit is to be obtained, and in order to have saturation with a reasonably low potential on the central system, it is necessary that the central cylinder shall be large. A large central system when afterwards introduced into the ionization chamber, so as to form the central system there, would, however, on account of the large capacity, reduce the sensitivity in the ionization-chamber measurements. For this reason the central system of the ionization-chamber is formed of a thin rod, and the foil, after removal from the inside cylinder, is bent over and made to line the walls of the ionization chamber with the active surface facing inwards. In this way the foil does not contribute to the capacity of the system. The height of the ionization-chamber is about twice the height of the foil cylinder, so that the latter occupies only the central portion of the wall of the chamber. In this way difficulties are avoided arising from the uncertainty which would otherwise be introduced in the fraction of the alpha particles traveling any assigned portion of their range in the vessel. The uncertainty referred to would be great in the case where an appreciable fraction of the alpha particles strikes the top or bottom of the vessel, since the distribution of active deposit on the foil is by no means uniform. The central system of the ionization-chamber is attached to a single fiber electroscope adjusted to a sensitivity of about 5 to 10 divisions per volt, and the potential is applied to the outer vessel, the whole being mounted on a gimbal.

The number of ions produced per cubic centimeter per second in a closed vessel is measured by observing the saturation current produced in a copper vessel of about 27 liters capacity. Here again the central system is connected to a single-fiber electroscope, and the potential is applied to the outer system, the whole instrument being mounted on a gimbal. The rod of the central system is insulated from the outer vessel by an amber ring surrounded by a brass collar which fits into a hard-rubber ring. The latter fits into the opening in the vessel, and by maintaining the brass collar at zero potential, leak from the outer vessel to the central system is avoided. The principle of using a sensitive single-fiber electroscope for measuring the alteration of potential of the central system, while the potential is applied to the outer vessel, secures, of course, great sensitivity and reduces leakage errors to a minimum.

In the case of all the electroscopes in the observatory, the measurements are made by noting the time required for the fiber to travel between two fixed marks on the scale, and the indications are reduced to volts in a moment by calibrating systems which are permanently connected to each instrument and are used in conjunction with a voltmeter common to all the systems.

The paper concludes with a discussion of the results of the third cruise of the *Carnegie*. (See next abstract.)

The atmospheric-electric observations on the third cruise of the *Carnegie*, 1914. Report and discussion by W. F. G. Swann. Terr. Mag., vol. 20, pp. 13–48 (March 1915).

The atmospheric-electric observations discussed in the report comprised the measurements made during the third cruise of the *Carnegie* while under the command of Mr. J. P. Ault, in 1914. The general course of the *Carnegie* during this cruise was as follows: Leaving Brooklyn on June 8, 1914, she arrived at Hammerfest on July 3. Sailing again from Hammerfest on July 25, she entered the harbor at Reykjavik, Iceland, on August 24, having reached the latitude of 79° 52′ north, off the northwest coast of Spitzbergen. Leaving Reykjavik on September 15, the *Carnegie* arrived at Greenport, Long Island, on October 12, returning to Brooklyn on October 21, 1914.

The observations in 1914 comprised, in addition to the magnetic and meteorological data, measurements of the potential-gradient, the conductivities for the positive and negative ions, and the radioactive content. Measurements of the ionic numbers were also made during the passage from Greenport through Long Island Sound to New York. All of the observations, with the exception of a few measurements in Long Island Sound by the author, were taken by Observer H. F. Johnston.

The first portion of the report is devoted to a description of the methods employed and to a general discussion of the sources of uncertainty. Measurements of the potential-gradient were made by means of an ionium collector attached to the end of a bamboo pole, and by the method described by the author in a former communication.[1] Measurements of the conductivity were made by Gerdien's method. The ionic content was measured by a modification of the Ebert ion counter and the radioactive content by a modification of Elster and Geitel's method.

The average value of the potential-gradient, atmospheric conductivity, and radioactive content for the whole cruise were, respectively, 93 volts per meter, 2.52×10^{-4} E. S. U., and 23, the last number being expressed in Elster and Geitel units. The average value of the Earth-air current for the whole cruise was 7.7×10^{-7} E. S. U. per square centimeter.

The atmospheric-electric elements were measured daily between the hours of 9 a. m. and 12 noon. The observations as far as they go indicate a general increase of the potential-gradient from summer to winter, which is in accord with land observations for the daily mean values. The conductivity also shows a general increase from the beginning of the cruise (June 8, 1914) to about the end of September, when a maximum occurs, after which the conductivity falls; the Earth-air current-density follows the general course of the conductivity. No very definite conclusions evolve as to the seasonal variations of the radioactive content, though the results are not inconsistent with those of Simpson in Lapland, in indicating a higher active content in winter than in summer. Table 4 shows the mean values of the various elements arranged according to the period as given in the first column, λ_+ and λ_- referring, respectively, to the conductivities for positive and negative ions. The quantity η in the last column is proportional to the radioactive content of the atmosphere.

[1]Terr. Mag., vol. 19 182–185, September 1914.

No marked variation of the atmospheric-electric elements with temperature or humidity was found; however, an indication is shown of a variation of the conductivity with latitude, a maximum for the latitudes involved occurring in the neighborhood of 50° north. These conclusions with regard to the variation of the elements with season, latitude, etc., must be looked upon as tentative, owing to the small number of data involved. A comparison has been made of the mean values of the conductivity for the several sections of the cruise, with the values to be expected as a result of the measured radioactive

TABLE 4.

Period, 1914.	$\lambda_+ + \lambda_-$ (E.S.U. $\times 10^{-4}$).	$\frac{\lambda_+}{\lambda_-}$	Pot. grad. (volts/meter).	Earth-air current (E.S.U. $\times 10^{-7}$).	$\eta \times 10^{-2}$.
June 13–June 23	2.24	1.21	75	5.6	62
June 23–June 30	2.43	1.12	90	6.8	109
July 27–Aug. 11	2.38	1.21	79	5.3	89
Aug. 12–Aug. 21	2.99	1.25	104	10.5	65
Sept. 15–Sept. 28	3.35	1.19	103	11.5	166
Sept. 29–Oct. 7	2.59	1.22	112	8.1	306

content. The results are given in table 5; they have been calculated by reducing the measured radioactive content to Elster and Geitel units and then making use of an empirical relation obtained by Kurz for the rate of production of ions per cubic centimeter corresponding to 1 Elster and Geitel unit. In the table, q represents the rate of production of ions per cubic centimeter owing to the radioactive material, and the number of ions (n) per cubic centimeter of either sign has been calculated from the expression $n^2 = q/\alpha$, where α is the coefficient of recombination of the ions and is taken as 1.56×10^{-6}. The conductivity is taken as $2nev$, v being the specific velocity of the ions. The value of v has been taken as 1.6 cm. per second per volt per centimeter for each sign of ions.

TABLE 5.

Passage.	q	$n_+ + n_-$.		$\lambda_+ + \lambda_-$.	
		Observed.	Calculated.	Observed (E.S.U. $\times 10^{-4}$).	Calculated (E.S.U. $\times 10^{-4}$).
New York to Hammerfest...	0.16	.....	.....	2.09	1.47
Hammerfest to Iceland......	0.15	.....	.....	2.69	1.43
Iceland to Greenport........	0.43	.....	.....	2.77	2.42
Long Island Sound, Oct. 19..	0.64	923	1,280	....	....
Long Island Sound, Oct. 21..	0.42	434	1,040	....	....

In the observations in Long Island Sound, n was measured directly for each kind of ion, and so it became possible there to compare the measured value of $n_+ + n_-$ with the calculated $2n$ without introducing the specific velocity of the ions. In the above calculated values the effect of the penetrating radiation from the active material in the sea has been neglected. This effect is very small, however. It will be seen that while in the Atlantic Ocean the radioactive material is sufficient to account for an appreciable fraction of the conductivity, it is by no means sufficient to account for all of it. It must further be borne in mind that in so far as many of the ions produced by the radioactive

material in the air undoubtedly go into the type of the slowly moving Langevin ions, the calculated conductivity should be even smaller; it is probably for this reason that the calculated values of $n_{+}+n_{-}$ for the Long Island Sound observations comes out even greater than the observed values.

The latter portion of the report is devoted to a mathematical discussion of the possibility of determining the nature and amount of active material in the atmosphere from an analysis of the decay curves for the active wire. It appears that the customary method of drawing conclusions as to the nature of the products in the atmosphere by comparing the decay curves for a wire exposed thereto with that of a wire exposed to emanation contained in a small closed vessel, is not justified. The activity curves are analyzed in the report, use being made of the theory of radioactive disintegration, and it is found that while some of the curves can be explained by radium emanation alone, others require the presence of a product of longer decay period than radium *A*, *B*, or *C*. The possibility of this extra product being a product of thorium emanation, as is generally assumed to be the case on land, is discussed by the author.

An attempt to calculate the actual amount of radium emanation in the air directly from the theory of the Elster and Geitel method, without assuming any empirical relation, results in a much smaller value for the emanation content than that given by the empirical relation, unless it is assumed that the average specific velocities of the active carriers are much smaller than is generally supposed.

The origin and maintenance of the Earth's charge. W. F. G. Swann. Read at the special meeting on atmospheric physics of section B of the American Association for the Advancement of Science, San Francisco, August 5, 1915. Terr. Mag. vol. 20, 105–126 (September 1915).

The paper consists of two parts. Part 1 is devoted to a general discussion of certain broad principles which must be considered in the formulation of any theory of atmospheric-electric phenomena, and to a consideration of former theories. In part 2 a new hypothesis is provisionally formulated, and its consequences are traced.

Part 1 commences by considering the possibility of a general circulation in the atmosphere by which the negative electricity flowing upwards at one place is conducted down at some other place. It appears that such an explanation is untenable, for no regions have been discovered presenting the phenomenon of a continual return current, and apart from this fact, the existence of a circulation of the kind depicted would necessitate that the electromotive forces around closed paths, in which the flow was taking place, would have to be of the order of magnitude of 10^5 volts. *Electrostatic* forces can contribute nothing whatever to a line-integral around a closed circuit. A consideration of such values of the line-integral as could be obtained on the basis of the change of magnetic induction due to the Earth's magnetic field through a closed circuit, or of the motion of the Earth and atmosphere in the magnetic lines of force of the Earth, shows that, apart from the circumstance that they would be of a nature unsuitable to correspond to the facts, they would be of an order of magnitude entirely too small to play any appreciable part in the phenomena.

The various possible types of hypotheses which may be made to account for the maintenance of the Earth's charge are capable of being grouped under three heads: (1) We may imagine that negative electricity is fed into the Earth from the outside in some unspecified manner. In this case it will be necessary to assume that the vertical conduction current is dissipated again into space. (2) We may imagine that negative electricity is supplied continuously to the Earth and positive electricity to the atmosphere at all places.

(3) We may imagine that negative electricity is supplied continuously to the Earth and positive electricity to the atmosphere, the supply taking place, however, over only a limited region at any one time.

Considering the hypotheses of the first type, it turns out that in view of the fact that the Earth is a comparatively good conductor of electricity, the charge will distribute itself uniformly over the Earth's surface. The known fact that the conductivity continually increases with altitude to a high value is all that is necessary to insure that things will arrange themselves so that the positive charge in the atmosphere is equal to the negative charge on the Earth.

Considering any hypothesis of type 3, it turns out that in regions where the replenishment of charge to the Earth and atmosphere is not taking place, the potential-gradient and Earth-air current-density would, under ordinary conditions, quickly fall to an insignificant value. If, however, a very high value is assumed for the conductivity of the upper atmosphere, this difficulty to some extent vanishes, and the assumption of a replenishment of the charge at one place is sufficient to account for the maintenance of atmospheric-electric phenomena at all places.

A discussion of several former theories is given; among others, those of Elster and Geitel and of Ebert. In these theories a separation of positive and negative electricity takes place in such a way that negative electricity is left on the Earth and positive is supplied to the atmosphere. The positive charge is carried upwards by the ascending air-currents, and in the steady state; the convection current so produced must be equal and opposite to the conduction current. Apart from the objections which have been raised by others against the Elster and Geitel theory, it is shown that, owing to the conductivity of the atmosphere, the rising positive electricity would become devoured, as it were, before it had reached any great altitudes, and the net result is that on such a theory the potential-gradient and Earth-air current-density would be expected to diminish to practically a zero value at altitudes of the order of magnitude of 1,000 meters, which is contrary to the results of balloon experiments. The objection here cited applies to any form of theory in which the convection current is supposed to balance the conduction current.

The hypothesis provisionally formulated in part 2 consists in assuming that each cubic centimeter of the atmosphere emits negative corpuscles of a penetrating power sufficiently great to enable them to travel through considerable thicknesses of the atmosphere. The Earth will absorb the corpuscles which fall upon it, and its potential will rise, in a negative sense, until the negative conduction-current back to the various parts of the atmosphere balances the charging effect due to the expulsion of the corpuscles. The total positive charge in the atmosphere will of necessity be equal to the negative charge on the surface of the Earth. In the steady state the resultant downward corpuscular current at any altitude will just balance the upward conduction current at that altitude. A general consideration of the order of magnitude of the phenomena concerned shows that it is only necessary to assume an extremely small rate of emission of corpuscles per cubic centimeter, and though the degree of penetration necessary for these corpuscles is greater than any we are familiar with in laboratory experiments, a full consideration of all the circumstances shows that the assumption is not as unreasonable as might at first sight be supposed.

In the simplest case, where the rate of emission of corpuscles and the average range of a corpuscle are independent of the altitude, the corpuscular current-density and consequently the conduction current-density should decrease to practically a zero value at an altitude comparable with the average range of a corpuscle. In the more general case where the rate of corpuscular emission

and the range of the corpuscles increases with the altitude, the variation of the conduction current-density with altitude becomes more complex, and it becomes possible in a natural way to explain on these lines the general features of the variation of the conduction current with altitude in so far as this variation is known. The argument in this connection is too involved to be made clear in an abstract, and a similar remark applies to a consideration of the question of annual and diurnal variation; it may be remarked, however, that the more prominent features of these variations fall into natural line with the conclusions resulting from the development of the hypothesis.

In conclusion, it is to be remarked that there is considerable latitude in the exact nature of the hypothesis which may be formulated in order to account for the general features of atmospheric-electric phenomena along the above lines.

Equipartition of energy and radiation theory. W. F. G. Swann. Read at the meeting of the American Physical Society in New York, October 30, 1915.

The paper commences with a general discussion of the basis of the theorem of equipartition of energy, after which an examination is made of the validity of certain conclusions usually considered to be necessarily associated with the theorem. The state of equipartition is one which is infinitely probable on a dynamical scheme when we adopt a certain mathematical concept of probability. It is argued that the infinite mathematical probability of this state, however, is by no means a criterion for the likelihood of its existence. The reasonableness of the view is borne out when we observe, for example, that the infinite value of the probability may very conceivably arise because the mathematics in the process of counting the configurations takes account of all those configurations which might be realized by the generalized coordinates of the system when all the matter, as we know it, has broken down into its ultimate constituents. In fact, the mathematics, in estimating the probability, takes account of all the universes which might have been made in addition to the one with which we are concerned, and, more particularly, it takes account of all the arrangements which would be possible in a universe in which there is no definite structure in matter. Several points for consideration in the above connection are discussed in the paper, but are too involved for presentation in an abstract.

The second portion of the paper considers the bearing of the theorem of equipartition of energy on the theory of radiation, and in particular it is argued that in an analysis which attempts to apply the laws of equipartition to radiation, the average energy of the fundamental degree of freedom should not be written as $\frac{RT}{2}$, where R is the gas-constant as ordinarily measured. Indeed, the very mechanism by which two gases come into temperature equilibrium when separated from each other, so that only radiation has play, is one which involves the internal coordinates of the molecules, and the conditions are not such that the average energy of the center of gravity of a molecule can in this case be equated to the average energy of one of the fundamental degrees of freedom. It is maintained that a subatomic analysis which attempts to include radiation should not be one in which the centers of gravity of gas-molecules figure at all as coordinates of the system. A difficulty presents itself, however, from the fact that the R which occurs in Rayleigh's formula $E_\lambda = 8\pi RT/\lambda^4$ is experimentally found to be the same number as that derived from other considerations involving measurements on gases direct, and from the fact that there is equipartition of energy among the energies of the centers of gravity of the molecules themselves. Many of the difficulties

in this and other connections are eliminated if we adopt the view that the radiation formula is fundamental in the form

$$E_\lambda = \frac{8\pi h\nu}{\lambda^4}\left(e^{\frac{a\nu}{T}} - 1\right)^{-1}$$

where h and a are constants, and that the approximate laws according to which molecules are acted upon by the fields in which they exist result in the average energy of a molecule situated in a field of radiation becoming $\mathrm{Lim}_{\nu=0}\lambda^4 E\ /8\pi$ *i. e.*, in this case, Th/a. This law becomes readily verified for the special case of an electron, and if its truth can be extended to molecules we see that it is not because R is the gas-constant that it occurs in the radiation formula, but rather that the gas-molecule moves with the average energy $\frac{RT}{2}$, per degree of freedom because this constant is involved in the radiation formula. On an extension of the above view, it becomes apparent that the form of E_λ as a function of the temperature is largely determined by the fact that we measure the temperature in such a way that this must be the case.

ARCHEOLOGY.

Morley, Sylvanus G., Santa Fe, New Mexico. *Research Associate in American Archeology.* (For previous report see Year Book No. 13.)

In December 1914 Mr. Morley submitted a report to the President suggesting the advisability of further field work at certain centers of the Maya civilization, notably La Honradez and Cancuén in northern Guatemala and Copan in western Honduras, before the publication of his report on the Maya hieroglyphic inscriptions then in course of preparation. This report having been approved, he came to Washington in January to arrange the details of the trip and to secure the necessary outfit therefor. It was planned that he should visit the three sites mentioned (and such others as he deemed pertinent to the object of the research); and that he should secure whatever additional data might be necessary for a complete presentation of their hieroglyphic texts.

In execution of this plan, Mr. Morley sailed from New Orleans for Belize, British Honduras, early in February, accompanied by Mr. J. P. Adams as assistant.

The itinerary followed is shown in plate 3. It divides conveniently into three parts, the objective in each case being one of the three sites mentioned above.

The first trip from Belize to the ruins of La Honradez and return took three weeks. The route lay at first up the Belize River to El Cayo, and thence northwestward through the dense tropical forests of northern Guatemala to La Honradez. The country is virtually a trackless jungle, the only inhabitants being a few mahogany cutters and chicle bleeders. The operations of the former are confined exclusively to the immediate vicinities of the few navigable streams, but the latter have traversed the bush hinterland in every direction in search of chicle, the principal ingredient of chewing-gum. Indeed, it is chiefly due to the activities of the chiclero that new archeological sites are discovered from time to time and that the intensive study of the antiquities of the region is made possible.

The second trip, to the ruins of Copan in the western part of Honduras, lay in a different direction. On March 15 the expedition sailed from Belize for Puerto Barrios, Guatemala, thence by rail inland to Zacapa, thence by mule-train two days' journey eastward to Copan. (See plate 3.) This region is entirely different in character from the densely forested, gently rolling plains of northern Guatemala.. It is traversed by ranges of high mountains, whose steeply sloping sides and the valleys at their feet are all cleared and under cultivation, chiefly in coffee. Much tobacco is also grown, the Copan Valley, in which the ruins are located, being particularly famed for the superior quality of its leaf, said to equal that of the finest Havana tobacco. This site

was one of the largest centers of the ancient Maya world, and is particularly rich in hieroglyphic texts, perhaps as high as 35 per cent of all known Maya inscriptions being found here. The copying and photographing of this material, much of which is new, consumed five weeks and the expedition did not return to Puerto Barrios until the last of April.

The third and last trip was the most difficult. The route (see plate 3) lay from Puerto Barrios to Livingston and thence up the Golfo Dulce and Río Polochic to Panzos, and thence by mule-train to Cahabon, in the department of Alta Vera Paz, one of the richest coffee-producing states in Guatemala. There are no mule-trails beyond Cahabon, and from this point it was necessary to proceed on foot, the baggage being borne by Indian carriers.

FIG. 3.—Map illustrating archeological investigations in Mexico and Central America. The circle incloses the region occupied by the Maya civilization.

After a week's journey through the bush in a northwesterly direction, the ruins of Cancuén on the Río de la Pasión were reached, and here the Indian carriers turned back. After an examination of this little-known site and the discovery of a new altar there the journey out was commenced on May 14.

The expedition proceeded down the Río de la Pasión in a mahogany dugout to Sayaxche, the headquarters of The American and Guatemalan Mahogany Export Company, and thence by mule-train to Flores, the picturesque little island-city on the Lake of Petén Itzá,

visited by Fernando Cortez in 1525 on his memorable and tragic march from Tabasco to the Gulf of Honduras.

After resting here a few days, the journey out to the coast was resumed, and on June 5 the expedition returned to Belize, thus closing a loop of over 1,000 miles of mule, foot, and motor-boat travel, which had taken three months almost to a day. In addition to the three sites, an examination of which was contemplated in the original plan, nine other ruin-groups were visited, as follows: Quirigua, La Reforma III, Seibal, Itsimte, Flores, San José de Motul, Yaxha, Benque Viejo, and Nakum; and new material was obtained at each.

The results, arising from the study of the various inscriptions at the foregoing twelve sites, may be summarized as follows:

First and most important, 7 new dated cities have been added to the 19 previously known, an increase of nearly 37 per cent in this direction, as follows: (1) La Honradez, (2) Cancuén, (3) Itsimte, (4) Flores, (5) Yaxha, (6) Nakum, and (7) Benque Viejo. The distribution of these is shown in figure 3, where the newly dated cities are represented by black dots and those the dates of which were previously known by crosses.

Four new monuments were discovered: a stela at Seibal, an altar at Cancuén, and an altar and a rock-cut shrine at Copan.

Eight new Initial Series were discovered: four at Copan, three at Itsimte, and one at Yaxha.

Ten new period-ending dates were discovered: two at Copan, two at Cancuén, two at Flores, two at Nakum, one at Seibal, and one at Benque Viejo. In addition to the foregoing, a large number of "corrected readings" of previously deciphered texts, as well as new readings of previously reported but heretofore undeciphered texts, were secured. Many of the earlier readings were found to be inaccurate, and a thorough revision of all previous decipherments was undertaken.

The general relation of this new material to the whole subject of Maya chronology is set forth graphically in figure 4. This figure shows the several periods of occupancy of the different southern cities based upon the dated monuments at each.

The successive 20-year periods of the Maya Era appear across the top of the figure, there being 20 years (7,200 days) between any two adjacent heavy black lines, *i. e.*, from 9.0.0.0.0 to 9.1.0.0.0 for example, and 5 years (1,800 days) between any two adjacent lines. The new dates appear in outline, previously known dates being shown in solid black.

It will be seen in figure 4 that all of the new dates, except the one from Yaxha, occur during the Great Period; and that not a few fall at its very close from 10.1.0.0.0 to 10.2.0.0.0 (580–600 A. D.). This is perhaps the most important single contribution of the expedition—that is, the accumulation of data tending to show that the Old Empire made its final stand in the northeastern corner of Guatemala, in what

is now the Department of Peten at the cities of Seibal, Flores, Tikal, Ucanal, Benque Viejo, Nakum, and Naranjo.

In the extreme south, at Copan and Quirigua, and in the west from Palenque southeastward, including the long chain of cities on the Usamacintla River (Piedras Negras, El Cayo, Yaxchilan, El Pabellón, Altar de Sacrificios, and Aguas Calientes) the practice of setting up monuments appears to have ceased by the end of Cycle 10, *i. e.*, 10.0.0.0.0; and the inference is reasonable that these centers had either been abandoned outright, or at least had sunk to such a low level of cultural activity as to be incapable of artistic and chronologic expression. Only in the northeastern part of Peten the light of culture was kept burning for a half century longer, to be extinguished finally by the great exodus which put an end to the Old Empire about the beginning of the seventh century A. D.

The swiftness with which the closing catastrophe fell, whatever may have been its nature, is apparent from the fact that not a single city of the Old Empire has a date later than 10.2.0.0.0, although a number of cities were surely occupied down to this time or twenty years prior thereto.

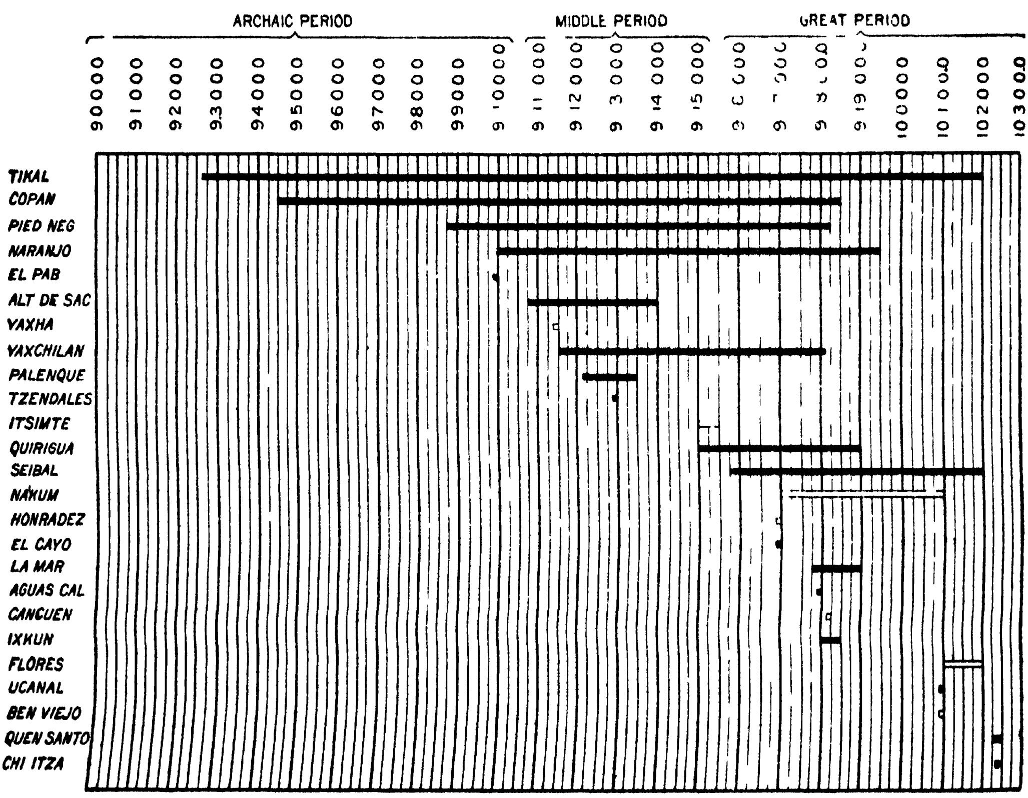
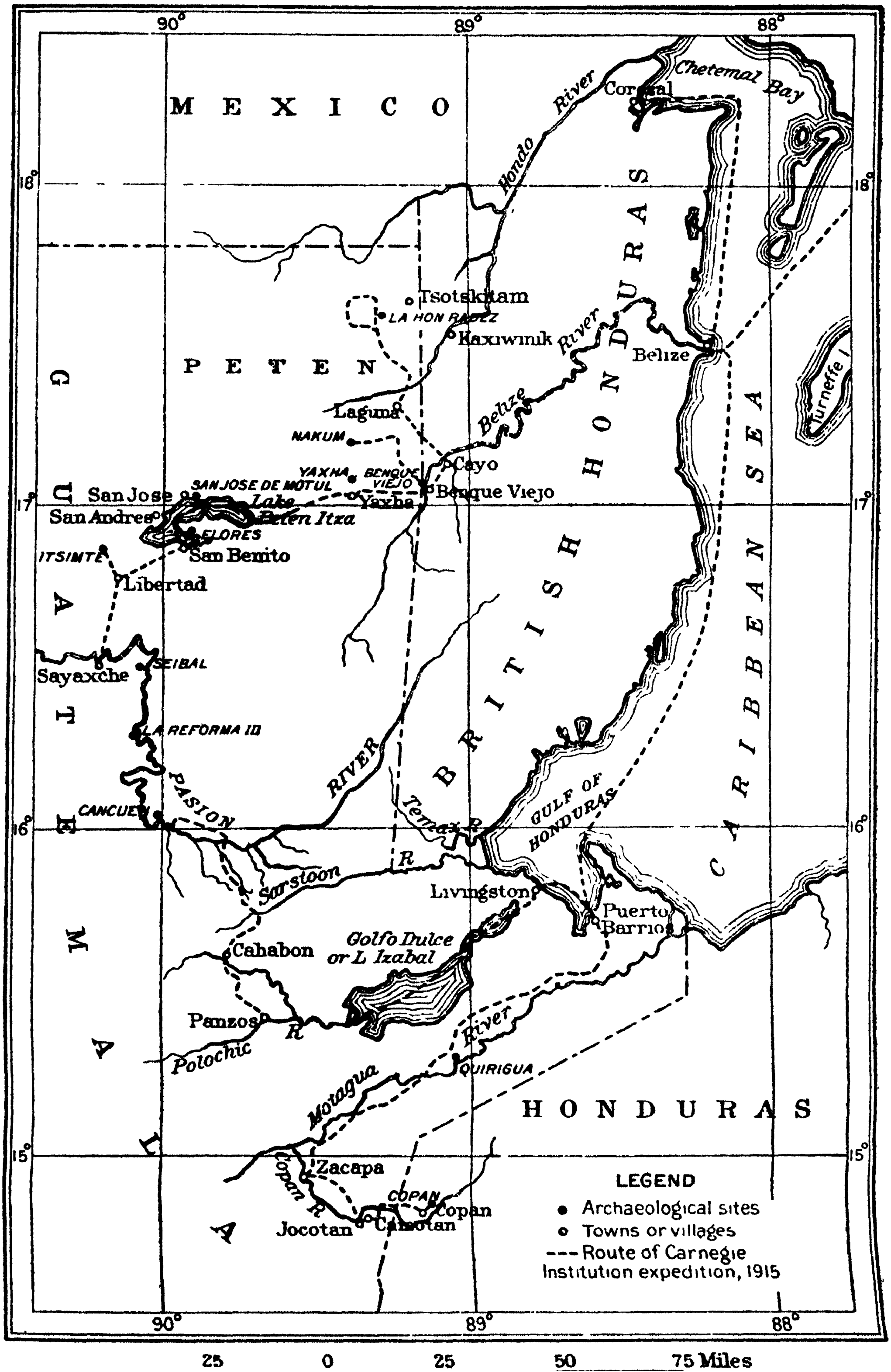


FIG. 4.—Diagram showing distribution of the new chronological material gathered by The Carnegie Institution Expedition in 1915. New dates are in outline, previously known dates in solid black.



Map showing the region traversed by The Carnegie Institution Central American Expedition in 1915.

Van Deman, Esther B., Rome, Italy. *Research Associate in Roman Archeology.* (For previous reports see Year Books Nos. 9–13.)

The summer and autumn months of 1914 were spent in Rome in the regular work of collecting and classifying the material for the general treatise on the development of Roman concrete construction, to which reference has been made in former reports. The remains of the monuments discovered in the older excavations, notably those of the early periods, the material of which is of an especially friable character, have suffered greatly from their long exposure to the weather. A careful review of the various reports concerning their condition at the time of their excavation was therefore necessary, to discover, if possible, any new data as to their original construction. In the compilation of the lists of the dated monuments of the later periods, also, it has been found necessary to make an exhaustive study of the older reports in which these buildings appear, as well as of the numerous reproductions of them in old prints and photographs, since many of the remains seen at an earlier time have now wholly disappeared. The original scope of the work, moreover, has been somewhat enlarged by including in the various lists those monuments of certain date in the vicinity of Rome which were immediately dependent upon the city for their methods of construction. Of these monuments, the most important are those of the ancient ports of Rome at Porto, Ostia, and Anzio, with the imperial villas scattered throughout the Campagna.

The winter was spent in America in the preparation and delivery, before various colleges, universities, and learned organizations, of a number of lectures concerning the work done in the past three years and its more important results in the fields of Roman archeology and topography. Among the institutions before which lectures were delivered are Barnard, Goucher, Holyoke, Oberlin, Vassar, and Wells Colleges, and the Universities of Chicago, Johns Hopkins, Missouri, Toronto, and the Western Reserve. A course of lectures, also, on the development of the Roman Forum, as shown by the materials and methods of construction used in the existing remains of its monuments, was given at the University of Pennsylvania.

On account of the uncertainty concerning the conditions for work in Italy in April, an immediate return to the field was deemed inadvisable. The spring and early summer were, therefore, spent in Washington, where those portions of the work on the development of concrete construction for which the materials were accessible were prepared for the press. During the months spent in Washington the work was carried on in the Administration Building of the Institution.

The pleasant relations established during the past years in Rome with the workers of other nationalities along the various lines of archeological research have continued to be very helpful as well as stimulating. In collaboration with the heads of several of the foreign schools

and with members of the staff of the University of Rome, the investigation of a number of larger problems in the archeological and topographical fields, for the solution of which the methods of construction are especially important, have been recently undertaken. Among the lines of investigation already well begun, that dealing with the ancient Roman aqueducts is of especial interest. In addition to the long and faithful study of them made by Dr. Thomas Ashby, Director of the British School in Rome, whose exhaustive work will, it is hoped, soon appear, the Royal School of Engineers of the University of Rome, under the direction of the distinguished Professor Reine, has generously offered its assistance in the difficult task of determining the levels of the widely scattered remains of the greater Anio group of aqueducts throughout their entire course, without a knowledge of which many of the historical and constructional problems are insoluble.

BIBLIOGRAPHY.

Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–13.)

The Index Medicus for 1914 contains 1,311 pages, 137 pages less than the issue for 1913. The annual index of the same contains 215 pages, 18 pages less than that of the preceding year. The number of pages contained in the issues from January to May 1915 is 465 as against 600 for January to May 1914. The cause of this falling off in quantity of material for indexing is of course to be found in the European War. With the exception of 5 German, 4 Italian, 1 French, and 1 Japanese journals, practically all the new periodicals issued during 1914–15 (up to August 30, 1915) are either American or English. These figures give a fair index of the rate of falling off in the literature of the different countries. Germany being so far free from invasion, and Italy having remained neutral until recently, these countries have led in the amount of European medical literature during 1914–15. All the prominent English medical periodicals are still printed, but the British Medical Journal, the leading English organ, contains 1,124 pages of text for July–December 1914, as against 1,652 pages for the same period in 1913, which is a fair indication of the extent to which the British journals have been thinned out. No medical journals from Russia and Poland for 1915 have been received. Switzerland, Holland, and the Scandinavian countries still keep up their quota in fitful fashion. The medical periodicals of Belgium are practically extinct.

A large proportion of the European periodical literature is taken up with gunshot wounds and military medicine. Under the latter rubric, special subdivisions of "Pediculosis" and "Poisonous and Suffocating Gases" have been made. A special subdivision of "Surgical Anæsthesia" has been added to "Surgery."

BIOLOGY.

Minot, Charles S., Harvard Medical School, Boston, Massachusetts. *Study of nuclei of cells in various vertebrates and other investigations in cytomorphosis.*

Dr. Minot died in November 1914, shortly after inaugurating investigations under the auspices of the Institution. His associate in research, Dr. A. S. Begg, was authorized, however, to continue investigations throughout the year for which the grant to Dr. Minot was made, and Dr. Begg's report upon such work is as follows:

Material was collected for the study of the relations of cell size and nuclear size, but this study was discontinued at Professor Minot's suggestion on account of his illness. The study of the abnormal arrangement of cardinal and portal venous systems in a 12 mm. pig embryo, with wax reconstruction, was completed, and also a model of corresponding veins in a normal pig embryo of like size. This was reported at the St. Louis meeting of the American Association of Anatomists, December 1914, and an abstract of the report was printed in the Anatomical Record (vol. 9, No. 1, page 56, January 20, 1915). A study was made of anomalies in the same region in man and other animals as reported in literature since 1670, involving approximately 200 articles and 250 cases. The completed paper covering the above, with illustrations, will appear shortly in one of the anatomical journals. A useful piece of laboratory apparatus was designed and was described as "A simplified form of drawing apparatus" in the Anatomical Record for September 1915.

A study of intestinal epithelium was begun and the material collected. It is hoped that this study will be carried sufficiently far for a report during the coming year.

CHEMISTRY.

Baxter, Gregory P., Harvard University, Cambridge, Mass. *Determination of atomic weights.* (For previous reports see Year Books Nos. 3–13.)

During the past year papers were published embodying results upon the atomic weights of cadmium, praseodymium, and lead, and upon the vapor-pressure of solid iodine.

Dr. F. L. Grover continued his investigation upon the atomic weights of non-radioactive lead, by the examination of additional samples of material (see Year Book No. 13). In all, 11 specimens of lead salts from many different geographical and mineralogical sources were prepared and found to be identical, so far as could be determined by spectroscopic examination and by analysis of the chloride and bromide. The atomic weight of common lead found in this way is 207.20 (Ag = 107.880). No indication was found that ordinary lead is composed either wholly or in part of isotopes of different atomic weights.

As a check upon the analysis of lead chloride and bromide by comparison with silver, Dr. Grover attempted to synthesize lead chromate quantitatively from metallic lead. While this salt possesses an unusually small solubility in neutral solutions, it was found to occlude and hold soluble lead salts very tenaciously, even when precipitation is carried out in very dilute solution.

Attention was next turned to the electrolytic determination of lead in the chloride by deposition in a mercury cathode. A long search was necessary to find a suitable washing liquid for lead amalgam. Finally, after Mr. Grover had been obliged to discontinue the research, Mr. Leon W. Parsons found that when especially pure ether is employed, the attacking of the amalgam, which ordinarily occurs, was hardly perceptible. No analytical results have as yet been obtained.

Interest in the identity of material from different sources, aroused by recent radioactive developments, made it desirable to compare nickel from terrestrial and meteoric sources, as has recently been done in the case of iron by Baxter and Thorvaldson and by Baxter and Hoover (see Year Books Nos. 9 and 11). This investigation was undertaken by Mr. Parsons.

Since in earlier work in the Harvard Laboratory by Richards and Cushman, nickelous bromide was the compound analyzed, in this work reduction of nickelous oxide in hydrogen was chosen, in order to provide a comparative method and furnish a direct ratio to oxygen.

The source of the terrestrial material was commercial nickelous nitrate, that of the meteoric material was the "Cumpas" meteorite, a generous portion of which was given us by Professor John E. Wolff, of the Harvard University Museum. Both samples were carefully freed from cobalt by crystallization of nickel ammonia nitrate, and finally, after nickel nitrate had been prepared from electrolytic metal,

it was ignited to oxide. As was to be expected (from the work of Richards), this oxide was found to contain a fairly large, but surprisingly constant, proportion of occluded gases, the proportion of which was carefully determined in each sample of oxide analyzed. It was further shown experimentally that nickelous oxide, at the temperature at which it was ignited, about 1000°, possesses an inappreciable oxygen pressure, and that oxide which has been ignited and cooled in an oxygen atmosphere of a few millimeters pressure does not gain in weight upon ignition and cooling in air, or even oxygen at atmospheric pressure. Hence the treatment of the oxide preliminary to weighing was simply prolonged ignition in air at about 1000°. After being weighed it was reduced in a current of electrolytic hydrogen in a quartz tube at about 1000°. No difficulty was experienced in securing constancy in weight of the metal, which was assumed to indicate complete reduction.

TABLE A.

Terrestrial.			Meteoric.		
Corrected weight of NiO in vacuum	Weight of Ni in vacuum.	Atomic weight of Ni.	Corrected weight of NiO in vacuum	Weight of Ni in vacuum.	Atomic weight of Ni.
gm	*gm*		*gm*	*gm.*	
6 41281	5 03957	58 717	6 65624	5 23021	58 683
6 10952	4 80102	58 703	4 45609	3 50196	58 724
6 91023	5 43006	58 697	4 64795	3 65212	58 676
4 60077	3 61528	58 696	....		... .
5 57122	4 37792	58 700	.	.	.....
5 59217	4 39445	58 704	.	.	..
Average .		58 703	Average		58 694
Average of all determinations			..	.	58 700

There seems to be no evidence of dissimilarity in the two specimens of material, an outcome in accord with earlier experience of the same kind. The results agree, as well as could be expected, with the one obtained by Richards and Cushman, 58.68 (Ag=107.880).

Mr. Merritt R. Grose continued the analysis of cadmium bromide, begun by Dr. Hartmann (see Year Book No. 13), by the electrolytic deposition of the cadmium upon a mercury cathode. The glass cell devised by Baxter and Hartmann for the analysis of cadmium chloride was equally useful here. It was found advisable, however, to bubble a slow current of hydrogen through the electrolyte in order to hasten the removal of the bromine liberated at the anode. As with the chloride, complete deposition of the cadmium was never secured, but the residual electrolyte was carefully evaporated with sulphuric acid and the very small amount of undeposited material was weighed as sulphate. In some experiments the cadmium bromide was all converted to sulphate before electrolysis. This modification had no perceptible effect upon the results.

TABLE B.

Cd : $CdBr_2$		Br = 79.916.	
Weight of $CdBr_2$ in vacuum.	Corrected weight of Cd in vacuum.	Ratio Cd : $CdBr_2$.	Atomic weight of cadmium.
gm.	*gm.*		
16.55663	6.83575	0.412871	112.394
6.83764	2.82343	.412925	112.419
7.47559	3.08670	.412904	112.410
7.16223	2.95696	.412857	112.387
9.44405	3.89967	.412924	112.419
6.71886	2.77414	.412888	112.402
10.31855	4.26111	.412956	112.434
9.40020	3.88142	.412908	112.412
8.21123	3.39038	.412896	112.406
10.51505	4.34153	.412887	112.402
10.22411	4.22156	.412901	112.409
10.99613	4.54012	.412883	112.400
11.05166	4.56316	.412896	112.405
19.67134	8.12244	.412907	112.411
Average.............		.412900	112.408

The result of these experiments with the bromide confirms closely that obtained by Baxter and Hartmann by electrolysis of cadmium chloride, as well as that found by Baxter and Hines by comparing both the chloride and bromide with silver, 112.417 (Ag = 107.880).

Mr. Grose also completed a series of electrolyses of zinc bromide by methods exactly similar to those used with the cadmium salt.

TABLE C.

Zn : $ZnBr_2$.		Br = 79.916.	
Weight of $ZnBr_2$ in vacuum.	Corrected weight of Zn in vacuum.	Ratio Zn : $ZnBr_2$.	Atomic weight of zinc.
gm.	*gm.*		
7.67096	2.22712	0.290331	65.389
8.02839	2.33122	.290372	65.402
7.18458	2.08517	.290229	65.356
7.55005	2.19181	.290304	65.380
7.71332	2.23937	.290325	65.387
7.11551	2.06599	.290350	65.395
7.44099	2.16047	.290347	65.393
7.18828	2.08727	.290371	65.401
Average............		.290329	65.388

This result is an interesting confirmation of that obtained by Richards and Rogers, 65.37 (Ag = 107.880), through the comparison of zinc bromide with silver, and thus lends weight to the value of the electrolytic method in general.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. *Continuation of investigations on the absorption spectra of solutions and on the conductivity and dissociation of electrolytes in water and in non-aqueous solvents at different temperatures.* (For previous reports see Year Books Nos. 2–13.)

A number of problems have been investigated during the year.

Dr. Davis has studied the effect of certain salts of cæsium on the viscosity of water and mixed solvents. It is known that some of the salts of potassium and rubidium lower the viscosity of the water in which they are dissolved. Jones and Veazey proposed an hypothesis which seems to account satisfactorily for this phenomenon. The large atomic volumes of potassium and rubidium diminish the surface friction of the molecules in solution moving over one another, just as larger bullets mixed with smaller shot diminish the frictional surfaces which come in contact with one another when these bodies move over each other. In the light of this suggestion, salts of cæsium should show a still greater diminution in the viscosity of water, since cæsium has a larger atomic volume than rubidium, which in turn is larger than that of potassium. The experimental facts are in perfect accord with the prediction from theory and are therefore regarded as evidence in favor of the theory.

Dr. Davis has also studied the viscosities of mixtures of water and formic acid, water and acetic acid, and formic and acetic acids, and compared the results with the viscosities of these solvents in the pure state. This work was undertaken in connection with the suggestion as to the cause of the change in viscosity above referred to. It is well known that a mixture of water and alcohol has much greater viscosity than either pure water or pure alcohol. Both of these solvents are strongly associated liquids. It was shown several years ago, by Jones and Murray, that when two associated solvents are mixed each diminishes the association of the other. Therefore, from a smaller number of larger molecules there results a larger number of smaller molecules, thus increasing the frictional surfaces and consequently the viscosity. Similar results should be obtained when associated liquids, such as those mentioned above, are mixed with one another. The viscosity of the mixture should be greater than that of either pure liquid alone. The experimental results are here again in perfect accord with the prediction from theory.

Dr. Davis has improved his method for regulating the temperature of baths, his thermo-regulator, all things considered, being one of the best now in existence. He has also devised a new substitute for the twin-bulb trap in toluol-mercury thermo-regulators; and, with L. S. Pratt, has also devised a new form of pyknometer for liquids.

Dr. Davis and Dr. Putnam have perfected a vacuum distilling apparatus in connection with their work on formamid and have suc-

ceeded in obtaining a product suitable for conductivity work. Hitherto the high specific conductivity of the solvent used by other investigators has prevented accurate conductivity measurements; but by their method of purification Davis and Putnam have prepared formamid comparable in conductivity with water.

They have studied the conductivities and viscosities of solutions of salts in formamid as a solvent. This solvent has a higher dielectric constant than water, and would therefore, from the Thomson-Nernst hypothesis, be expected to have greater dissociating power, and such has been found to be the fact. The effect of dissolved salts on the viscosity of formamid is similar to their effect on water. It is a function of the ionic volumes of the dissolved ions.

Dr. Shaeffer and Dr. Paulus have studied the absorption spectra of indicators by means of the new Littrow spectroscope designed by Professor Anderson, and an improved radiomicrometer. A very sensitive thermoelectric junction was built by Dr. Guy, and his radiomicrometer was the most sensitive that had been constructed up to that time. Shaeffer greatly improved the form of junction constructed by Guy, and built an automatically compensating junction which gave far more satisfactory results.

In the Littrow spectroscope, designed by J. A. Anderson, a plain 4-inch grating was used, the lenses having been made by Brashear.

By means of the improved radiomicrometer and the large grating spectroscope, the positions and especially the *intensities* of absorption lines and bands could be measured with a much higher degree of accuracy than had been hitherto possible. The constants of a number of the more common indicators were worked out with considerable certainty, and about 20 times more accurately than had been previously done. The numerical values of these constants must be known with reasonable accuracy, in order that these indicators may be used scientifically in quantitative analysis.

The work of Dr. Shaeffer and Dr. Paulus was extended by Dr. Paulus and Mr. Hutchinson to corallin, using the same apparatus that Shaeffer and Paulus had employed. A satisfactory constant was also obtained for this indicator.

Jones and Anderson, in Publication 110 of the Carnegie Institution of Washington, showed that when certain salts with sharp absorption lines and bands were dissolved in certain non-absorbing solvents, the resulting absorption spectra were a function of the nature of the solvent in which the salt was dissolved; for example, neodymium chloride in water had a quite different spectrum from neodymium chloride in methyl alcohol. The existence of well-defined "solvent bands" was thus established for the first time.

A large number of such "solvent bands" for a large number of solvents, and for a fairly large number of dissolved salts, were dis-

covered by Jones and Strong. These results have been recorded in Publications 130 and 160 of the Carnegie Institution of Washington. They were able to distinguish, for example, between the absorption spectrum of a salt dissolved in an alcohol and in its isomer.

The existence of "solvent bands" was explained in terms of the solvate theory of solution as proposed by Jones. The combined solvent had different resonants, and, therefore, different power to absorb light from the free or uncombined solvent.

Jones and Guy (Publication 190 of the Carnegie Institution of Washington), from a quantitative study of the intensities of the absorption lines and bands by means of the radiomicrometer already referred to, found that solutions of slightly hydrated salts absorbed to just about the same extent as pure water; while solutions of strongly hydrated salt, such as calcium and magnesium chlorides, were as much as 30 per cent more transparent than pure water. This showed that combined water had less resonance and, therefore, less power to absorb light than free water.

Shaeffer and Paulus repeated these investigations, and obtained the same general results that had been earlier found by Jones and Guy. They showed that solutions of certain very strongly hydrated salts were as much as 40 per cent more transparent than pure water, thus establishing a marked *physical difference* between free and combined water as illustrated by their action on light. These results have appeared in Publication 210 of the Carnegie Institution of Washington.

Having found this physical difference between free and combined water, the question arose, is there any difference in the *chemical activity* of free water and of water of hydration? To test this, Dr. J. E. L. Holmes took up the study of a reaction effected by water alone, the saponification or hydrolysis of an ester, breaking it down into the free acid and the free alcohol. The rate of decomposition as effected by pure water alone was first measured. The rate of decomposition in the presence of slightly hydrated salts, such as potassium chloride and nitrate, was determined; and finally the rate of decomposition of the ester in the presence of such strongly hydrated salts as calcium chloride, magnesium chloride, etc., was measured.

The action of a fairly large number of both of these classes of salts, on the decomposition of methyl formate and methyl acetate, was studied. The results indicate that the chemical activity of combined water, as determined by means of the saponification of an ester, is greater than that of free water.

Mr. Connolly studied the hydration of acetic anhydride by water alone, also in the presence of only slightly hydrated salts, and finally, in the presence of strongly hydrated salts. This work has not proceeded far enough to justify us in drawing any final conclusion.

The work of Dr. Wightman and Mr. Wiesel on the conductivity of organic acids in ethyl alcohol has been greatly extended during the past year by Dr. Lloyd and Mr. Wiesel. Nearly 40 organic acids have been studied by these investigators in this solvent. The conductivity of organic acids in general in ethyl alcohol is surprisingly small when we consider the relative dissociating powers of water and ethyl alcohol in their action on salts. The temperature coefficients of conductivity of the organic acids in this solvent are large.

Dr. Watkins has extended the work on the conductivity and dissociation of salts in water, as measured by their conductivity, which has been in progress for the past 15 years, and the results of which have appeared in Publication 170 of the Carnegie Institution of Washington. He has worked with a number of rather unusual salts with very great care, over a wide range of dilution, and at several temperatures. The results obtained in general confirm the conclusions drawn from earlier work on this same general subject.

Mr. Ordemann has investigated the relative dissociating powers of free and of combined water, in the following manner. He prepared isochloric solutions of potassium chloride and calcium chloride, the one only a slightly hydrated and the other a strongly hydrated compound. These solutions were used as a solvent: in one, nearly all of the water existing as free water; in the other much of the water being combined with the calcium chloride as water of hydration.

Certain salts were dissolved in these two solvents, and the dissociations of the salts in question were measured by means of the conductivity method. The two solutions were made isochloric, in order to drive back the dissociation of the dissolved salts to the same extent. While the results thus far obtained are too few in number to justify the drawing of any final conclusion, it seems highly probable, from what has already been done, that combined water or water of hydration has less power to break down dissolved molecules into their ions than free or uncombined water.

The problem of absorption or adsorption of certain substances by soils has been studied by Mr. McCall, with the cooperation of Messrs. Hildebrandt, Johnston, F. G. Holmes, and Trelease. They found that the potassium from solutions of potassium chloride is partly combined chemically with or absorbed by the soil particles, and partly adsorbed or held physically by the soil particles; the fineness of the division of the soil having a marked effect on the amount of the potassium salt absorbed or combined chemically, and also that adsorbed or in a condition of physical combination. It appears that, under certain conditions, the solvent water may be adsorbed even more rapidly than the salts.

The results of these investigations are recorded in Publication 230 of the Carnegie Institution of Washington, published in October 1915.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. ***Measurement of the osmotic pressure of solutions.*** **(For previous reports see Year Books Nos. 2–13.)**

The monograph on "The Osmotic Pressure of Aqueous Solutions," which was issued by the Carnegie Institution of Washington (Publication 198) in June 1914, contained a brief account of all the work of the author which had been brought to a definite conclusion up to that time. At the close of the paper it was announced that the work of the immediate future would consist in the measurement of the osmotic pressure of glucose, cane-sugar, and mannite solutions at temperatures above and below those which had been previously employed with these substances; also that the measurement of the osmotic pressure of levulose solutions would be undertaken. The work of the past year has been mainly along the lines thus indicated.

It had been shown in the monograph referred to: (1) that at low temperatures (under 25°) the ratio of osmotic to calculated gas-pressure is greater than unity in solutions of glucose; (2) that at temperatures between 30° and 50° the ratio is unity when the weight-normal system of making solutions is employed. In other words, it had been established that within the latter temperature-interval the osmotic pressure of glucose solutions obeys the laws of Gay-Lussac and Boyle for gases. The excessive ratios of osmotic to gas pressure which were observed at the lower temperatures were ascribed, provisionally, to a concentration of the solutions through hydration of the solute; and it was suggested that the observed subsequent decline in all ratios to unity is due to a dehydration of the solute at the higher temperatures, by which process the solutions would necessarily suffer some dilution, that is, an increase in the proportion of solvent to solute. The validity of such explanations depends, in a great measure, however, on the ratio of osmotic to calculated gas pressure at still higher temperatures, *i. e.*, at temperatures above 50°. If the ratio, having once declined to unity at some temperature (30° in the case of glucose), persistently maintains that value at all higher temperatures, the correctness of the explanation of the excessive ratios observed at the lower temperatures (as due to hydration of the solvent) would seem to be fairly well established.

Very great importance is therefore to be ascribed to the measurement of osmotic pressure at high temperatures; since it is through such observations that we shall probably arrive at the correct explanation of the fact that at low temperatures the ratios of osmotic to gas pressure are as a rule excessive, *i. e.*, greater than unity. The difficulties which are experienced in measuring osmotic pressure correctly are very great, even at low temperatures; but at high temperatures they become almost insuperable, and the progress of the work is sometimes for several months almost imperceptible. Nevertheless, we have succeeded, since the publication of the monograph referred to above, in completing satisfactorily a long series of measurements of the osmotic pressure of glucose solutions at 60°. Ten concentrations of solution

were employed, ranging from 0.1 to 1.0 weight-normal. The ratios of osmotic to gas pressure which were observed are, respectively: 1.001, 1.004, 1.001, 0.999, 0.999, 1.001, 1.001, 1.001, 1.002, and 1.001; showing that at 60°, as well as between 30° and 50°, the osmotic pressure of glucose solutions obeys the gas laws. Material for future work has been prepared by subjecting large quantities of glucose (Traubenzucker Kahlbaum) to the elaborate process of purification which was described in the monograph previously cited.

In the case of cane-sugar it had been shown also that, at low temperatures, the ratio of osmotic to calculated gas pressure is always considerably above unity; but that, at some temperature between 30° and 80°, the ratio in every concentration of solution up to 1.0 weight-normal declines to unity. It was suggested, as in the case of glucose, that the excessive ratios observed at low temperatures, and their gradual decline through a higher range of temperature—eventually to unity—could be explained most readily by imputing to the solute a definite hydration at the lower temperatures. It was presumed that such hydrates, if formed, would necessarily become unstable at some more elevated temperatures and begin to dilute the solutions by increasing the proportion of solvent, and that we should therefore observe, above the initial temperature of instability, a progressive decline in the ratio of osmotic to gas pressure, which would continue until the solute becomes anhydrous.

The measurement of the osmotic pressure of cane-sugar solutions had previously been carried to 60° for the 0.1, 0.2, 0.3, and 0.4 weight-normal solutions; to 70° for the 0.5, 0.6, and 0.7 solutions; and to 80° for the 0.8, 0.9, and 1.0 concentrations. In other words, the measurement of the pressure of all the solutions had been carried at least up to the temperature at which the ratio of osmotic to gas pressure became unity, and the solute appeared, therefore, to be obeying the gas laws.

It was regarded as highly important to carry the measurement of the osmotic pressure of cane-sugar solutions to still higher temperatures, not only for the purpose of ascertaining whether the gas laws continue to prevail, but also to secure additional evidence as to the cause of the excessive ratios of osmotic to gas pressure at low temperatures. For more than a year we had been preparing and developing a new series of cells with which it was intended to resume the work on cane-sugar at high temperatures. When, however, it was attempted to use these cells, it was found that they were "too slow," that the time required for the establishment of "equilibrium pressures" in them was so great that the slow auto-inversion of cane-sugar which takes place at high temperatures became sensible in quantity—that is, detectable by the method of Fehling and by the polariscope. It was therefore necessary to suspend the work on cane-sugar at high temperatures until a new series of "quicker" cells could be prepared. The magnitude and difficulty of such an undertaking can be realized only by those who are actively engaged in the investigation; but a statement regarding

only a few of the qualities of osmotic cells which are unconditionally essential to the correct measurement of pressure will serve to impress others with the fact that the labor involved is very great, and the chances of disappointment very many.

The membrane must consist of an infinite number of little plugs driven tightly into the inner mouths of the cell pores. A membrane of any other structure or location is useless. If it merely covers the inner surface of the cell, it can not resist pressure. If, on the other hand, it is located within the cell-wall at a distance from the inner surface, difficulties due to retarded diffusion occur. The inner surface is, then, always bathed by a diluted solution and the pressures observed are neither constant nor at any time the true osmotic pressure of the solutions. Inasmuch as the membranes are formed electrolytically by the meeting of certain oppositely moving anions and cations, provision must be made such that the meetings can occur only in the right place, *i. e.*, just within the mouths of the pores which open on the inner surface of the cell-wall. This condition is secured by so regulating the size of the pores that, while the large and slowly moving anion is just entering the mouths of the pores from within, the smaller and more rapidly moving cation can pass nearly through the cell-wall.

The proper regulation of the texture of the cell-wall is a matter of great delicacy and difficulty. If the pores are too large, the membrane is formed too far within the wall; if they are too small, the membrane is deposited on the interior surface of the cell-wall. In either case, the cell is worthless for the measurement of osmotic pressure. We divide into two classes those cells in which the membranes are properly located, designated as "quick" and "slow." In cells of the former class, the pores are (within permissible limits) relatively large, and the membranes, therefore, have considerable active area, which accounts for the rapidity with which equilibrium pressures are established. In the second class the pores are relatively small, and the cells are slow in developing pressure because the effective area of the membranes is small.

The required fineness of texture in the cell-wall is secured: (1) by elutriating the clays and using only the finer products; (2) by subjecting the clay to enormous pressure while forming the cell; and (3) by burning the cells at high temperature. Each process plays its part in determining the eventual size of the cell-pores, and each has been made the subject of elaborate investigation. The baking of the cell is the most critical of all the operations determining the size of the pores, because it is the last one to which the cell is subjected.

In former years, as stated elsewhere, our cells had been burned at the Chesapeake Pottery. With the cooperation of the officials of that concern, and after much investigation, it was determined under just what conditions, as to location in the kilns, number of repetitions of the baking process, etc., cells of the required texture could be produced. Unfortunately for the progress of our work, the Chesapeake Pottery

suspended its operations permanently about two years ago. We had at the time an accumulated supply of cells which was sufficient only to carry on the work through a part of the following year. The baking and glazing of the cells was immediately transferred to the Bennett Pottery; but it was necessary to repeat, in the new location, the elaborate series of experiments previously made at the Chesapeake Pottery. This work has been under the direction of Dr. Holland. It is by no means finished, but he is already producing usable cells.

The present problem, which is being worked out with good promise of success at the pottery, is the production of cells so *active* that the osmotic pressure of cane-sugar solutions in them will reach equilibrium before the auto-inversion of the sugar, which occurs above 60°, reaches a sensible magnitude. A few fairly successful measurements of pressure at 70° have already been accomplished in cells of recent make.

One important development of the past year has been the construction of a cell for the measurement of very high pressures. It has already been successfully employed for the determination of pressures exceeding 125 atmospheres.

The osmotic pressure of mannite is of especial interest because the freezing-points of its solutions—unlike those of solutions of glucose and cane-sugar—are normal. In the author's report to the Carnegie Institution, previously cited, it was shown that, between 10° and 40°, the osmotic pressure of mannite solutions is also normal, *i. e.*, that within this temperature-interval it conforms to the gas laws. Only a few measurements of the osmotic pressure of mannite solutions have been made during the past year, and all of these were, as before, within the temperature-limits, 10° to 40°. They were made with a view to the introduction of the interferometer as a means of ascertaining concentration, rather than to secure additional osmotic data. Measurements of pressure below 10° and above 40° have not yet been attempted.

A considerable number of measurements of the osmotic pressure of levulose at 30° have been made during the past year. In view of the general similarity of conduct on the part of the two substances, it was to be presumed that levulose would be found to exhibit the same osmotic peculiarities that had been observed in the case of glucose—in other words, that the osmotic pressure of levulose solutions at low temperatures would be found to be seemingly greater than is required by the gas laws; and that the ratio of osmotic to gas pressure at low temperatures would decline to unity at some higher temperature and thereafter remain constant. The temperature at which this ratio became unity for all solutions of glucose was 30°. This temperature was therefore selected for beginning the work upon levulose.

The costly material for this investigation was provided by Dr. Hudson, of Washington. It was nearly pure when it came into our hands, and required but little further treatment to render it entirely suitable for our purposes.

Measurements have already been made in solutions ranging in concentration from 0.1 to 0.7 weight-normal. The observed ratios of osmotic to gas pressure are practically identical for all concentrations, as in the case of glucose; but they are all somewhat *above* unity, the mean of all being 1.015. It would seem, therefore—speaking in terms of the assumption that abnormally high osmotic pressure at low temperature is probably due to hydration—that the temperature required to dehydrate the solute completely is somewhat higher in the case of levulose than in that of glucose.

To the writer and to those associated with him in the study of osmotic pressure, it has always appeared highly desirable that the scope of the work should be extended to include a study of the vapor tension of the solutions under investigation. The great advantages of such coordination are too obvious to require discussion, and it would have been attempted long ago were it not for the fact that, until recently, we have had no sufficiently precise and practicable method for the measurement of vapor tension. All obstacles in the way of a simultaneous study of the two phenomena—osmotic pressure and vapor tension—have now been removed by Doctors Frazer and Lovelace, who, through their long-continued cooperative efforts, have succeeded in developing a thoroughly practicable method of high precision for the measurement of vapor tension. They have already accumulated much reliable and valuable data concerning some of the solutions whose osmotic pressure had previously been studied. In the future, it is expected to continue concurrently both lines of research, as nearly as possible.

Noyes, Arthur A., Massachusetts Institute of Technology, Boston, Massachusetts. *Researches upon the properties of solutions in relation to the ionic theory.* (For previous reports see Year Books Nos. 2–13.)

During the past year the investigations, referred to in previous reports, on the equilibrium relations of oxidizing and reducing agents and on the electromotive forces of concentration-cells have been continued.

The study of the equilibrium between the metals bismuth and copper and their chlorides BiOCl and CuCl in the presence of hydrochloric acid has been completed with the assistance of Mr. M. Chow. The experimental determination of the equilibrium conditions of the reaction between plumbous chloride and chlorine has been continued by Mr. E. W. Wescott, and an investigation by a colorimetric method of the equilibrium between the manganate, permanganate, ferrocyanide, and ferricyanide of potassium has been undertaken and carried through with the assistance of Mr. A. W. Mudge.

The investigation of the electromotive force of cells of the type H_2, HCl, Hg_2Cl_2+Hg has been continued by Mr. J. H. Ellis. It may be recalled that the purpose of this line of research is to determine the

magnitude of the deviations from the laws of perfect solutions which largely ionized solutes exhibit. At hydrochloric-acid concentrations between 0.1 and 2.0 normal very satisfactory results have been obtained, showing that the activities of the ions of the acid pass through a pronounced minimum between these concentrations. More dilute solutions have offered difficulties which require further investigation.

Incidentally to the investigation of the bismuth-copper equilibrium, Mr. F. W. Hall has determined the solubility of bismuth oxychloride in hydrochloric acid of various concentrations, with the view of determining the bismuth anion-complexes formed in such solutions.

Finally, reference may be made to the fact that a monograph by F. G. Keyes and R. B. Brownlee, on the thermodynamic constants of ammonia, consisting mainly of "ammonia tables" for the use of engineers, analogous to the well-known "steam tables," is now ready for publication and will be issued within a few months. The new experimental investigations on which these tables were based, though not directly supported by the grants from the Carnegie Institution of Washington, were carried out in this laboratory in close connection with the similar research made with the aid of those grants by Mr. R. D. Mailey on the thermodynamic properties of water at high temperatures.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigation of atomic weights and other physico-chemical properties of the elements and simple compounds.* (For previous reports see Year Books Nos. 2–13.)

During the past winter (1914–1915) the number of assistants contributing to the laboratory work in the Wolcott Gibbs Memorial Laboratory was smaller than last year, because it happened that every one of the eleven men assisting during 1913–1914 had been obliged to leave in order to undertake more lucrative employment. Accordingly, with an entirely new corps of assistants, only seven investigations were prosecuted in the laboratory during the winter. These are described below. The comparative freedom from superintendence of laboratory work was welcomed as an opportunity to collate and publish previous investigations; and fourteen papers, all more or less directly concerning work done with the help of these grants, have been published since the last report. They represent the expenditure of much time and thought. These papers, which afford a much fuller report of the work than is possible in brief abstract, are recorded by title in the bibliography of the Year Book. The laboratory work during the winter of 1914–1915 was as follows:

1. Atomic Weight of Lead Obtained from Radioactive Minerals.

The work upon this subject which was described in the last Year Book was avowedly preliminary. Although its outcome has been confirmed by other less extended researches carried on both in France and

Austria, the need of further light upon the highly interesting and pressing problems which it suggests was imperative. Therefore, with the help of Mr. Charles Wadsworth, 3d, this work has been continued in the laboratory this year. New specimens of radioactive lead, sent by the kindness of Professor Charles L. Parsons, of Washington, D. C., Mr. S. Radcliff, of Australia, and Dr. Ellen Gleditsch, of Kristiania, have been carefully studied in the manner already described, and, although the investigation is not quite ripe for definite publication, it is far enough advanced to confirm in every respect the earlier work. Particularly the Australian radioactive lead was found to have a very low atomic weight, at least as low as the lead from North Carolina uraninite, and no impurity was detected in its ultra-violet spectrum, in amount capable of producing anything like this effect. Evidently, then, an impurity very similar to lead must exist in radioactive lead; and this impurity can not be separated from it by a moderate number of crystallizations, first of the nitrate and then of the chloride. That some other property of this admixture besides the atomic weight must be different from that of pure lead one can hardly doubt, and the many chemical and physical properties of the Australian lead are, therefore, under investigation. During the coming winter every effort will be made to effect the separation and identification of the admixed element. More material than that heretofore available is necessary to solve the problem.

2. Causes of Inclusion in the Silver Voltameter.

This investigation also is a continuation of the work on this subject carried out last year. During the present winter the work was in charge of Mr. Norris Folger Hall, who obtained many interesting results on varying inclusion, showing that a number of circumstances tend to affect this quantity and, therefore, the weight of the gently heated silver deposited in the silver coulometer. In general, conditions were found which made possible the inclusion of distinctly less mother liquor than that found during the previous winter, with the help of Dr. Frederick O. Anderegg, but the results point to the same conclusion as before, namely, that the amount of inclusion should be determined before one can be sure of the true weight of the precipitate. The details of this investigation also are not quite ready for publication; and, like the preceding, it will be continued during the coming academic year.

3. The Standardization of the Thermometric Scale.

During the preceding winter, by means of a thermochemical method, a new method of standardizing or subdividing the thermometric scale was devised. It consisted in carrying out a mild physico-chemical reaction again and again, each time beginning the reaction (which evolved enough heat to raise the reacting system about 0.2°) at the final temperature of the previous trial. Knowing the change of heat

capacity of the system during the reaction, one could compute the energy-change at each temperature, and therefore the amounts of heat needed to cause the successive definite rises of temperature. Upon introducing the small correction involved by the changing specific heat of water, it was possible to subdivide the thermoelectric scale by these successive steps, and the results indicated that the 18° point of our standard thermometers was thermodynamically somewhat above that half-way point between 16° and 20°.

The exact amount of this deviation was not fully decided; more experiments were needed. Accordingly, during this last winter, with the help of Dr. Sekuro Tamaru, a somewhat similar method of subdividing the thermometric scale was employed, this time taking the energy from a galvanic current passing through a known constant resistance. The process, which involves experimentation precisely like that in a common method of determining the varying specific heat of water, enables us to determine the errors of our thermometers over this range if we assume the relative specific heats of water between 16° and 20° to be known. Many different trials were made, and all except one (which was undoubtedly complicated by an accidental error) agreed in giving essentially the same appreciation of the thermometric error at 18° as that given by the previous thermochemical work with Dr. Thorvaldson, although the deviation was not quite so great as that shown before. The thermometric scale thus constituted seems to be the best of any yet at our disposal, but it will be subject to yet further scrutiny and analysis. Much depends upon the correct solution of this problem, because a large amount of thermochemical work carried out by Dr. A. W. Rowe and others, with the help of these grants, is waiting for codification and publication until the thermometric observations, made carefully with the excellent thermometers, can be reduced to the true thermodynamic scale. Next winter it is proposed to verify the conclusions by reference to the best electrical-resistance thermometers and thermoelectric couples obtainable.

4. The Heat of Solution of Metals.

This problem was undertaken in continuation of the work done by Dr. Thorvaldson last year, with the new apparatus devised with his help. The present investigator was Dr. Tamaru, who not only repeated Dr. Thorvaldson's results with zinc, but also carried out similar determinations with cadmium, as well as a number of determinations of the specific heat of the solutions involved. The results with zinc agreed very well with those of Dr. Thorvaldson, and there is therefore good reason to believe (because the method gives identical results in different hands) that the outcome for zinc is to be depended upon and that for cadmium is also trustworthy.

5. Further Study of Compressibility of Elements and Compounds.

With the help of Mr. James Hallett Hodges, the study of compressibility both of elements and compounds was continued. Dr. Weintraub, of the General Electric Company, courteously loaned to us a fine and unusually compact specimen of pure boron for the purpose of determining its compressibility, which was measured for the first time. This element shows, as would have been expected from the previous Harvard researches upon this subject, a very small compressibility (0.0000003), consistent with its small atomic volume and high melting-point. The compressibilities of various other substances, especially hydrocarbons and alcohols, were also determined with great care, using the new steel piezometer mentioned in the last Year Book, the determinations being made both at 20° and at 0°. Several improvements in technique were introduced. The outcome of the recent work upon compressibility of the elements conducted with these grants has provided data for 38 elements, which agree essentially (in those few cases where others have worked upon similar material) with the best preceding work. This being the case, it seemed worth while to consider the relations of these accurately determined data with other properties of the elements in question, and a preliminary paper upon this subject, recording certain empirical relationships between compressibility, atomic volume, melting-point, and coefficient of expansion, was published and is recorded on page 37 of this volume.

6. The Effect of Pressure upon Solubility.

Thermodynamically, the nature of the effect of pressure upon solubility of salts is clear, but, nevertheless, it seemed worth while to make a careful study of the facts, in order to verify the thermodynamic relationship, as well as to correlate this phenomenon with modern theories concerning the nature of the solution of electrolytes. Accordingly, with the help of Dr. Herbert Fowler Sill, a comparatively simple and very efficient apparatus for determining solubilities under pressure was devised, and careful experiments were made with solutions of sodium chloride, potassium chloride and bromide, and barium hydroxide. Care was taken to obtain saturation, through the approach of equilibrium from opposite directions. In order to apply thermodynamic reasoning to these results, the heats of solution of the substances at the saturation point was necessary, in addition to other data furnished by the researches of others. Accordingly, these were determined with the help of the adiabatic calorimeter. The results thus obtained give calculated values for solubility under different pressures, confirming within a reasonable limit of error all the experimental work, and supporting Baxter's interpretation of the conditions holding in solutions of these electrolytes, in accordance with the dissociation theory and the hypothesis of compressible atoms.

7. THE EFFECTS OF ISOMORPHOUS IMPURITIES ON THE TRANSITION TEMPERATURES OF CRYSTALLIZED SALTS.

This investigation is a continuation of one carried on last year with Dr. W. B. Meldrum, who investigated the effects of isomorphous impurities on the transition temperature of sodium chromate. During the present year similar series of experiments were made with the assistance of Mr. Victor Yngve, this time upon the transition temperature of various mixtures of pure strontium chloride and bromide, analyzing with care the composition of the mother liquor. The behavior of these salts was found to be different from that of sodium sulphate and chromate. The addition of strontium bromide to the chloride does not raise the transition temperature of strontium chloride, but causes it to diminish. A minimum is reached 6.4° below the transition temperature of the chloride, when the mother liquor contains nearly equal mol-percentages of strontium bromide and chloride. Evidently the phenomenon in question is concerned with the distribution of the impurity between the liquid and solid solutions, and this, of course, varies in every specific case. Incidentally, the temperature of transition from $SrCl_2 6H_2O$ to $SrCl_2 4H_2O$ was accurately determined for the first time in relation to the international hydrogen scale, and found to be 61.336°, while that of the bromide was found to be 88.2°.

Because a large number of exceptionally able assistants have arranged to work at the laboratory during 1915–16, it is hoped that more extensive series of investigations may be undertaken next winter.

Sherman, H. C., Columbia University, New York, New York. *Continuation of the chemical investigation of the amylases.* (For previous reports see Year Books Nos. 11–13.

During the past year this investigation has been continued in accordance with the plans outlined in previous reports.

Repeated experiments in the purification of pancreatic and malt amylases have provided material which has been utilized in a more complete comparison of these enzymes with each other and with the malt amylase described by Osborne in 1895 and 1896. Osborne's theory of the chemical nature of the malt enzyme has been shown to be applicable to pancreatic amylase also. By an amplification and extension of this theory, for the discussion of which reference must be made to the more detailed report, it has been possible to offer what appears to be a fairly adequate and entirely consistent explanation of the somewhat complex phenomena observed in studying the purification, activity, and deterioration of both the pancreatic and malt amylases. Two papers dealing with this phase of the work have been published in the Journal of the American Chemical Society (March and May 1915).

The experiments to determine the optimum concentrations of different acid substances as activators of malt amylase, referred to in the report

of last year, have been completed. These experiments show that this enzyme exerts its optimum saccharogenic activity at the definite hydrogen ion concentration (determined by the electrometric method and expressed in Sorensen's notation) of $P_H^+ = 4.4 \pm 0.2$, irrespective of whether this reaction is obtained by the addition of a strong acid (hydrochloric, nitric, sulphuric), a weak acid (acetic, propionic, phosphoric), or a weakly acid salt (primary sodium or potassium phosphate). These results were published in full in the Journal of the American Chemical Society for March 1915. An analogous study of the optimum hydrogen ion concentration for pancreatic amylase is now in progress.

Purification experiments upon the amylase of *Aspergillus oryzæ* have resulted in products of about twenty-five times the activity of the commercial preparations from this fungus. The laboratory purification results in a rise of nitrogen content along with diastatic activity, but the best preparations yet obtained are less highly nitrogenous and have less saccharogenic power than the purified preparations of either pancreatic or malt amylase. While further work upon the purification of this amylase is contemplated, the experiments already completed have provided material for certain comparisons with the pancreatic and malt amylases.

The question whether maltose or glucose should be considered the true end-product of the action of amylase upon starch has been studied, using the three amylases above mentioned both in the natural or commercial and in the purified forms. In all of these cases, under conditions such as obtain in the determination of diastatic power, maltose is found to be the chief reducing sugar formed. In general it so far predominates as to justify the custom of calculating the reducing power of the products of amylase action as due to maltose. The formation of a small amount of glucose, even by the purified amylases, is, however, demonstrable in experiments which are sufficiently prolonged, and the relative amount of glucose formed is plainly greater in the case of the fungus amylase.

Our unexpected discovery of three years ago, that purified pancreatic amylase is also an active protease, has been briefly noted in previous publications. Having made during the past year a comparative examination of several methods for the study of proteolytic action, a more detailed investigation of the proteolytic activity of our purified amylase preparations is now being undertaken.

The activation of the amylases by neutral salts and the development of a better method for the determination of amyloclastic power are also under investigation, and we hope to take up in the near future a detailed quantitative study of the course of the reaction of starch hydrolysis under the influence of purified amylases of different origin.

The efficient aid of the collaborators in this investigation, whether as research assistants or volunteers, is gratefully acknowledged.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–13.)

The larger part of the year was given to a continuance of the inquiry into the derivation of the earth's primary features from the mode of its growth and from its adjustment to the stresses that arose during its formative stages. The ultimate purpose of this inquiry is to deduce, if possible, the secular status and the dynamic conditions of the interior as well as the exterior of the earth which were thus transmitted to its later history and became its chief controlling factors. July and August were spent at Mount Wilson Observatory at the invitation of its Director in the preparation of a system of tentative working interpretations of nebulæ based essentially on dynamic considerations, with a view to serviceability in systematic researches on the nature and history of nebulæ and their evolutionary place in the stellar system.

Vaughan, T. Wayland, U. S. Geological Survey, Washington, District of Columbia. *Study of the stratigraphic geology and of the fossil corals and associated organisms in several of the smaller West Indian Islands.* (For previous report see Year Book No. 13.)

An account of the expedition to the northern Leeward and Virgin Islands in January to March 1914, with a statement of its objects, was given in the Year Book of the Institution for 1914, pp. 358–360. It was also stated that the collections of fossils had received the necessary preparatory work, had been sorted and segregated according to the respective groups represented, and had been distributed among specialists for study. As the manuscripts on the collections are now either complete or nearing completion, a report on their present status, according to the groups represented, is here rendered. Before making the statement it should be said that the standards for the geologic correlations are derived from the Coastal Plain of the southeastern United States and from Panama, where the stratigraphic succession is accurately known. An attempt is being made biologically to characterize each of the geologic formations in each of these regions, and reports covering the paleobotany and the invertebrate paleontology for the entire succession for both regions are rapidly nearing completion. Many volumes have already been published or submitted for publication by the U. S. Geological Survey and U. S. National Museum, besides those issued by other institutions. The specialists studying the West Indian collections are those making the regional studies for the southeastern United States and Panama, thereby having a proper basis for comparing floras or faunas throughout the areas bounding the Caribbean Sea and the Gulf of Mexico.

Dr. Marshall A. Howe, of the New York Botanical Garden, has completed his manuscript on the calcareous algæ. One new species of *Archæolithothamnium* from Antigua is most nearly related to a living species from Sulu Archipelago, Borneo, and Celebes, while another species from Antigua, though probably distinct specifically, is apparently related to *Lithothamnium vaughani* from the Oligocene of the Panama Canal Zone.

Professor E. W. Berry, of Johns Hopkins University and of the U. S. Geological Survey, reports that he has recognized in Antiguan fossil woods several forms which also occur on the Isthmus of Panama. They are sufficient to indicate an Oligocene age, and when the large collections of similar remains from the Oligocene Catahoula and Vicksburg formations of the southern United States have been studied it may be possible to make some definite correlations. This statement is based on a preliminary examination of the material.

Dr. Joseph A. Cushman, of the U. S. Geological Survey, who has completed monographs of the Pliocene and Miocene foraminifera of the Coastal Plain of the United States and of all the fossil foraminifera contained in the collections from the Canal Zone, is studying the fossil foraminifera of the West Indies. He is at present engaged on a monograph of the genus *Orbitoides*, which is largely represented in the upper Eocene and Oligocene deposits of the southern United States, Central America, and the West Indies. As soon as practicable, in addition to the one on *Orbitoides*, he will submit a general report on the other fossil foraminifera from the West Indies. The collections have already been sorted according to the different species.

Previous to my expedition, I had described and figured, with very few exceptions, all known fossil West Indian corals. The additional material has been prepared and sorted into species, and most of those already described have been identified. A few months will suffice to incorporate descriptions of the new material in my manuscript and to have the monograph ready for press. Deductions as to the geologic ages indicated by these organisms were published in the Year Book for 1914, pp. 359–360, and other notes appeared in the Journal of the Washington Academy of Sciences.[1]

Dr. R. T. Jackson has identified the fossil echinoids collected in Antigua, St. Bartholomew, and Anguilla, and has in preparation a general report on the fossil echinoids of the West Indies and Central America. Photographic illustrations of the types of the species described by Guppy and Cotteau from the Lesser Antilles, all of which are the property of the U. S. National Museum, have been made. It was noted in the last Year Book, p. 360, that *Echinolampas semiorbis* Guppy is common to the Emperador limestone, Panama, and to the argillaceous limestone of Anguilla. The type is from the latter locality.

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[1]Vol. 5, pp. 489–490, 1915.

Dr. C. Wythe Cooke, of the U. S. Geological Survey, reports, regarding the mollusks and brachiopods, that he has described about 106 species, of which about 45 are new. There are 35 species from Cuba, 13 from St. Bartholomew, 35 from Anguilla, and 27 from Antigua. The manuscript is practically finished, but some revision and editing is necessary. The mollusca from Anguilla indicate stratigraphic affinities with the Tampa horizon of the Oligocene.

Dr. R. S. Bassler, of the U. S. National Mueseum, and Mr. Ferdinand Canu, of Versailles, France, who are studying the fossil Bryozoa, report that the description and illustration of the specimens is complete and that a fauna of about 15 species has been noted from the several localities. In the matter of correlation, the faunas from Antigua, Anguilla, and Panama seem to indicate the same general age equivalence—that is, upper Oligocene. The Anguilla and Panama faunas apparently represent the same horizon, as there are a few species in common, while the species from Antigua, although there is none common to this fauna and the other two areas, are still so closely related to upper Oligocene Bryozoa that there can be little doubt that they are of this age.

Miss Mary J. Rathbun has completed a manuscript on the decapod Crustacea obtained in the Leeward Islands. All the species are new, and include a crab from St. Bartholomew and two shrimps and an anomuran crab from Anguilla. This collection will be supplemented by that obtained many years ago in Santo Domingo by W. M. Gabb and loaned by the Philadelphia Academy of Natural Sciences; it will add 6 species hitherto unknown.

Besides the paleontologic investigations enumerated, Dr. Paul Bartsch is studying the Recent land mollusca collected in the Leeward Islands, and such other material as is available, for the light they may throw on former land connections between islands and the time of their severance because of submergence. He hopes to complete his report before the end of the coming winter.

Stratigraphic deductions from the paleontologic investigations, so far as they have progressed, are indicated in the preceding notes. As they are corroborative of those already published in the two citations given, they will not be elaborated. My deductions were based principally on the fossil coral faunas, with some supplementary evidence from the foraminifera, echinoids, and mollusks.

Dr. D. F. MacDonald, of the U. S. Geological Survey, is studying the lithologic material, mostly volcanic and intrusive rocks. Thin sections of 55 specimens were cut in the laboratory of the U. S. Geological Survey.

It was stated in the Year Book for 1914, p. 358, that one object of the expedition was "to study the physiography of the islands in order to get a basis for making deductions as to how the conditions were

brought about under which the living coral reefs have formed." Evidence has been presented showing conclusively that Antigua, the islands standing above the St. Martin Plateau, St. Croix, and the Virgin group have undergone geologically Recent submergence.[1] Should the sea-level have remained stationary for a period of appreciable length antecedent to this submergence, there should be a submerged scarp indicating its former stand; should there have been a succession of temporary stands there should be a series of submarine terrace flats, separated by scarps. In other words, there should be a submarine physiographic record, which, if it could be recovered, should be as readily deciphered as a subaerial record. The only available sources of information were the charts of the U. S. Hydrographic Office and of the British Admiralty. Two areas were selected for special study, the Virgin Bank, east of Porto Rico, and the St. Martin Plateau. The charts of the former area are on a scale of slightly more than 1 mile to an inch; that of the latter is on a scale of 2.5 miles to 1.06 inches. These charts were contoured on a 2-fathom (12 feet) interval from the shore to a depth of 40 fathoms, and on an interval of 10 fathoms (60 feet) from 40 to 100 fathoms. This method of treatment brought out well-developed submarine terraces, as well as other submarine physiographic features, especially on the windward side of the banks. Although the charts need further study, certain features are clear and some of them will be briefly characterized.

On the north side of St. Thomas there is an extensive outer flat, bounded on its landward side by a steep escarpment, which in places is nearly 160 feet high. The landward margin of the plain is between 26 and 28 fathoms in depth; the seaward margin has a depth between 30 and 34 fathoms; the width is as great as 10 miles and for distances as great as 8.5 miles the range in relief of the surface is as small as 2 fathoms, in depths between 29 and 31 fathoms. Its outer margin is cut by reentrants which have bottoms about 40 fathoms deep and which simulate hanging valleys. There are also, near the outer margin of this terrace, banks or ridges, the upper surfaces of which are relatively flat, between 17 and 20 fathoms in depth. One of these banks has a total basal width of about 4 miles and a length of more than 5 miles. As its form is not that of a coral reef, it can only be the base of what was an island, which had been reduced almost to a smooth surface by marine plantation and then submerged, as indicated by other evidence. As all the other shoals with one exception are truncated at nearly the same level, it seems that they should be ascribed to a similar origin. These shoals usually show escarpments between 20 and 30 fathoms on their windward sides and more gradual slopes on the leeward sides. The outer flat is a submarine plain, which several lines of evidence

[1] Bull. Amer. Geograph. Soc., vol. 46, pp. 426–429, 1914.

show was developed when the sea-level was about 20 fathoms, or slightly more, lower than now. The escarpment extending from the islands north of Culebra Island, east of Porto Rico, and along the north side of St. Thomas, and the escarpment on the seaward face of the outlying shoals, apparently can be explained in no other way.

The indentations on the outer margin of the outer flat may have been caused by elevation and stream-cutting after its formation, or they may be due to initial marginal irregularities which have not been obliterated.

The approximate accordance in level of the tops of the outlying shoals at depths between 17 and 20 fathoms has been mentioned. These summits accord in height with a flat or gently sloping zone lying above and nearer shore than the deeper flat. It is scarcely represented on the seaward side of the promontories, viz, Cockroach and Cricket rocks, and Outer Brass and Little Hans Lollik islands. However, it spreads out on the flanks of the promontories and ranges from 0.5 mile to nearly 1.5 miles in width; it is separated on its seaward side by a steep slope or escarpment from the deeper flat and on its landward side by an escarpment about 36 feet in height from a terrace which has a depth of 7 to 10 fathoms. The descent is sudden from the shore to about 6 fathoms, which is near the inner margin of the highest submarine terrace. This terrace, also, is narrow on the tips of the promontories mentioned, but widens on their flanks and below the shores of the main island.

The submerged valley in Charlotte Amalia Harbor has a depth of 10 fathoms.

The interpretation of the history of the higher flats is beset with difficulties. Their narrowness or absence on the promontory tips suggests that they may be older than the deeper flat and were cut away during its formation, and that subsequent to the formation of the latter, after perhaps a brief interval of still lower stand of sea-level, the entire area has been resubmerged, perhaps to an amount somewhat exceeding the initial submergence.

The relations on the windward side of the St. Martin Plateau are similar to those north of St. Thomas, except that the boundaries of the upper terraces do not seem so definite. This may be due to fewer soundings and the smaller scale of the map. The outer, deeper flat, from 26 to 36 fathoms in depth, has a length east and west of over 30 miles. The scarp on its landward side is distinct and in places is about 50 feet high, between 20 and 28 fathoms, as off the east end of Scrub Island, east of Anguilla Island. The contouring of the bottom around Antigua Island has not been completed, but enough has been done to show that it also is terraced.

As the interpretation of the data accumulated is still incomplete, deductions here presented are only preliminary. The subject is

brought up partly to call the attention of geologists to a method of research which promises important results. As indicating an extension of such investigations, it will be said that arrangements have been made with the geologists associated or cooperating with the Coastal Plain investigations of the U. S. Geological Survey to make studies similar to those mentioned for the continental shelf along the entire Atlantic and Gulf borders of the United States and for most of Central America. References to such studies in the area off the Florida coral-reef tract will be found on pp. 236–237 of this Year Book.

With regard to the locus of the living reefs in the West Indies, it will be said that they have grown upon these terraces either during or subsequent to submergence, and conform to the principles found to govern their development on Mosquito and Campeche Banks, off Honduras, and in Florida.[1] (See pp. 233–238 of this Year Book.)

Attention has also been paid to the causes producing changes in position of strand line in Recent geologic time. As the subject is a vast and complicated one, although the body of information on Pleistocene and Recent strand-line movements is rapidly increasing, all that should at present be expected in interpretation is the formulation of working hypotheses. Professor Joseph Barrell, of Yale University, has cooperated by writing an article entitled "Factors in movements of the strand line and their results in the Pleistocene and Post-Pleistocene,"[2] and Professor W. J. Humphreys, of the U. S. Weather Bureau, has reconsidered the subject "Changes of sea-level due to changes of ocean volume."[3] The continued critical investigation of shore-line phenomena, it is hoped, will render possible the discrimination of results which may be due to local causes from those which may be due to general causes, and ultimately lead to the discovery of whatever general causes may have been operative, and should they be multiple, supply a basis for the evaluation of the effects ascribable to each.

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[1]R. T. Hill, although he did not elaborate the theme, was perhaps the first to recognize the relations living coral reefs bear to submerged terrace surfaces. In his "Geology and physical geography of Jamaica," Bull. Mus. Comp. Zool., vol. 34, pp. 99–100, 1899, he says, after describing the elevated reefs: "That Jamaica was once a more extensive land than now, with benched and terraced margins which were submerged by subsidence, is shown not only by the adjacent submarine configuration but by the elevated reefs themselves, such as that at Barbican, which can be seen to be clearly deposited upon a surface horizontally eroded across the vertical structure of the old Blue Mountain Series. Similar submerged plains are now occupied by the growing reefs around the island." An article by E. C. Andrews, entitled "Relations of coral reefs to crust movements in the Fiji Islands" (Amer. Journ. Sci., 4th ser., vol. 41, pp. 135–141, 1916), should be read in this connection.

[2]Published in full, Amer. Journ. Sci., 4th ser., vol. 40, pp. 1–22, July 1915. The paper was read before the Geological Society of Washington, March 24, 1915, and an abstract, entitled "Factors in movements of the strand line," with discussion of it, appeared in Journ. Wash. Acad. Sci., vol. 5, pp. 413–420, 444–447, 1915.

[3]Journ. Wash. Acad. Sci., vol. 5, pp. 445–446, 1915.

HISTORY.

Andrews, Charles M., Yale University, New Haven, Connecticut. *Preparation of a general history of the colonies in America.*

Professor Andrews worked during part of June in Hartford, Connecticut, among the archives of the State Library, and after August 1 he studied the manuscript records in the New York Public Library. This work will be supplemented in September by investigations among other collections in New York City, notably in the library of the New York Historical Society. Except in the form of occasional notes and articles no publications are likely to result from these researches for some time to come.

Bandelier, Adolf F., New York, N. Y. *Completion of a documentary history of the Rio Grande Pueblo Indians of New Mexico.* (For previous reports see Year Books Nos. 11-13.)

Dr. Bandelier died in March 1914 and since that date his widow, Mrs. Fanny R. Bandelier, has been continuing investigations, under the auspices of the Institution, in the archives in Seville, Spain, making copies and extracts of manuscripts bearing upon the subject in hand.

Osgood, Herbert L., Columbia University, New York, New York. *Completion of an institutional history of the American colonies during the period of the French wars.* (For previous reports see Year Books Nos. 11-13.)

Work on Professor Osgood's History of the American Colonies in the eighteenth century has progressed steadily during the past year. Since his return from Europe last September all of the time which he could spare from teaching has been devoted to the organization of the material which was then obtained and of other material procured in this country, and to the writing of additional chapters. Work on the colonies from New York to Georgia is nearly completed to 1750. During the present summer his time is being devoted to New England.

Since the beginning of last March Dr. Elmer B. Russell, a graduate of Columbia, has acted as an assistant. He has worked mainly at Boston and Worcester, Massachusetts, and has rendered valuable assistance in collecting material from the archives and from pamphlets and newspapers. A thorough examination of the newspapers and of rare pamphlets is necessary if one is to present a reliable and exhaustive discussion of political development in the colonies.

Much more work also needs to be done in the Public Record Office in London in order to clear up obscure points in the history of imperial control.

CLASSICS OF INTERNATIONAL LAW.

Scott, James Brown, General Editor, Washington, District of Columbia. *Preparation and publication of the Classics of International Law.* (For previous reports see Year Books Nos. 9–12.)

No volumes in this series have been issued during the past year. It may be stated, however, that the following works are in press:

Legnano: *De Bello, de Represaliis, et de Duello* (1360, first printed in 1477).
Vitoria: *De Indis* and *De Jure Belli,* contained in the *Relectiones Theologicæ,* first published in 1557.
Grotius: *De Jure Belli ac Pacis Libri Tres* (1625).
Rachel: *De Jure Naturæ et Gentium* (1676).
Textor: *Synopsis Juris Gentium* (1680).
Vattel: *Le Droit des Gens ou Principes de la Loi Naturelle Appliqués à la Conduite et aux Affaires des Nations et des Souverains* (1758).

The texts of these classics have been photographically reproduced by the Institution and the preparation of translations of the texts and of introductions, with accompanying English translations where necessary, is in progress. It is probable that most of these works will be issued during the coming year. It may also be stated that, with a view to ultimate publication, arrangements have been made for translations of the following classics:

Gentilis: *De Jure Belli, Advocatio Hispanica,* and *De Legationibus.*
Wolff: *Jus Gentium.*
Bynkershoek: *De Dominio Maris* and *Quæstiones Juris Publici*

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Completion of preparation for publication of an edition of Lydgate's Fall of Princes.* (For previous reports see Year Books Nos. 11–13.)

In March, April, and May Dr. Bergen collated all doubtful points in the text of the "Fall of Princes" with the British Museum MSS., Harley 4203 and Royal 18. B. XXXI, and with R. Tottel's printed edition of 1554. Since then he has been engaged in otherwise preparing the text for the press. This work is now well under way. He has also brought the glossary of the "Troy Book" down to those parts of the letters *S* and *T* of the Oxford Dictionary which were published in the spring of this year and expects soon to have the glossary of Lydgate's "Troy Book" brought up level with the Oxford Dictionary and copied out for the press. He has gathered material sufficient for the completion of the edition of the "Fall of Princes" down to the final corrections and the description of a few manuscripts in private libraries, not yet seen.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. *Application of Cremona groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9–13.)

During the past year Professor A. B. Coble has continued his researches on point sets and allied Cremona Groups. The results are embodied in a memoir in three parts. The first of these appeared in the Transactions of the American Mathematical Society for April 1915. The other two should be completed for publication this fall. An abstract of parts II and III appeared in the Proceedings of the National Academy of Sciences, May 1915.

Professor Coble has also in hand a study of the relations between point sets and theta functions. Professor Corner, a former associate under the grant, has completed the work which as associate he undertook in a memoir on "The Rational Space Sextic and the Cayley Symmetroid," which appeared in the American Journal of Mathematics, April 1915.

MATHEMATICAL PHYSICS.

Moulton, F. R., University of Chicago, Chicago, Illinois. *Investigations in cosmogony and celestial mechanics.* (For previous reports see Year Books Nos. 4, 5, 8–13.)

The unpublished investigations of the past year are as follows:

(1) *Computations on periodic orbits.*—The discovery of critical periodic orbits, closed orbits of ejection, and orbits of ejection and collision, by computation for the purpose of establishing the relations among the various families of periodic orbits, has been continued and is now complete.

(2) *Asymptotic orbits.*—Certain classes of asymptotic orbits are important in a general survey of the field of periodic orbits. A considerable number of asymptotic orbits have been computed.

(3) *The solution of an infinite system of equations of the analytic type.*—This problem was originally suggested by certain processes employed by Hill in his Lunar Theory, and whose validity he did not prove. By a special application of the results reached, Hill's method is justified in a suitably restricted domain. The work of Poincaré and von Koch on infinite determinants and infinite system of linear equations had already completed the logic in Hill's work on the motion of the moon's perigee. The present investigation fills the final gap in his work on the Lunar Theory. But this is only a single application; it enables one to show, among other things, the possibility of the expansion of the coefficients of the Fourier developments of certain elliptic functions as power series in the parameters on which they depend.

METEOROLOGY.

Bjerknes, V., University of Leipzig, Leipzig, Germany. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–13.)

The preparatory investigations for the third volume of "Dynamic Meteorology and Hydrography" have been continued. A complete account of the results obtained hitherto relating to the influence of friction upon atmospheric motions has been published by Messrs. Hesselberg and Sverdrup. Indirect results of these investigations on friction are marked by Hesselberg's papers "Ueber die Beziehung zwischen Luftdruck und Wind im nichtstationären Fall," "Ueber eine Beziehung zwischen Druckgradient, Wind und Gradientenänderung" and that of Hesselberg and Sverdrup "Windänderung mit der Höhe vom Erdboden bis etwa 3000 m Höhe" (Beitr. z. Ph. d. fr. Atm., in print). A subject of great practical importance has been treated in a paper of Hesselberg and Friedmann "Die Grössenordnung der meteorologischen Elemente und ihrer räumlichen und zeitlichen Ableitungen." The results contained in this paper have proved to be of great use for our further work.

Another new subject which has been taken up is that of internal atmospheric wave-motions. The principal mathematical problems forming the base of these investigations have been solved and a preliminary communication concerning the results has been given in the paper of V. Bjerknes "Theoretisch meteorologische Mitteilungen" (Met. Zeitschrift, in print). These investigations on wave-motions will form the introduction to further ones concerning the important subject of the stability of cyclones and anticyclones.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–13.)

Since our earlier experience has shown that marked differences exist between some of the proteins which are abundant constituents of many of the important foods of men and animals, we have devoted much attention during the present year to studying the relative nutritive value of certain proteins, both for growth and maintenance.

In determining the optimum proportion of food protein for either growth or maintenance it has been the usual practice of students of animal nutrition to observe the effect of feeding mixtures of natural foodstuffs containing different percentages of protein. Experiments of this kind have been planned to furnish a sufficient supply of calories in the non-protein part of the ration and reduce the proportion of protein by adding food substances low in protein or by diminishing the proportion of those rich in protein. All of this has involved changes in so many factors with every alteration in the food mixture that the results have value only in respect to the particular mixture used for the animal in question and are therefore to a very large extent empirical. Furthermore, possible differences in the relative efficiency of different proteins were formerly never considered in making such experiments; and the possibility of effecting economies in the use of the many available foodstuffs by so combining them that any nutritive deficiencies of the proteins of one food might be supplemented by proper combinations with another has heretofore generally escaped notice.

In studying these questions food was supplied *ad libitum* to rats in order to first learn the quantity of food naturally eaten by them under the conditions of our experiments. The limits of variation of food intake between different individuals could thus be determined. If such differences were great the food intake, referred to some definite standard, such as body-weight or body-surface, must be taken into consideration before minor differences between proteins of different origin can be detected.

These experiments showed that this method of study, though adequate to indicate grosser inequalities between the proteins from a nutritive standpoint, is not suitable for making more accurate comparisons. The limitations of the method lie in the fact that there is a wide difference in the amount of food eaten by different individuals, even of the same size and sex. Thus, by eating larger quantities of a ration low in protein an animal may consume a far greater absolute amount of protein than control individuals which consume less food containing the same percentage of protein. For this reason it became necessary to compare the absolute amount of protein eaten by the

different individuals. Where animals are given food *ad libitum* it is essential to obtain the data in a statistical manner from large numbers of experiments. The varying total of ingested calories is likewise a factor which must be taken into consideration.

Despite these unquestioned shortcomings the statistics which we have already gathered confirm our previously expressed views regarding the unlike nutritive value of some of the albuminous foodstuffs. In order to bring out this feature more sharply it is obviously desirable to ascertain the protein minima for both growth and maintenance and to institute comparisons on this basis. We have thus found that quantities of lactalbumin smaller than those of any other protein tested suffice to meet the requirements of *maintenance* as well as for growth. A résumé of the range of protein minima for maintenance found in the individual experiments is given in the following table:

Range of protein minima for maintenance in individual experiments.

Protein added to the ration.	Males.			Females.		
	Weight of rats.	Food intake per week per gram of rat.	Protein intake per week per gram of rat.	Weight of rats.	Food intake per week per gram of rat.	Protein intake per week per gram of rat.
	gm.	*mgm.*	*mgm.*	*gm.*	*mgm.*	*mgm.*
Lactalbumin..	60 to 100	361 to 557	3.9 to 9.9	80 to 100	356 to 417	5.5 to 6.9
	100 200	292 366	7.3 12.1	100 200	255 372	8.4 15.4
	200 250	241 288	10.4 14.5	....	....	....
	250 300	232 335	9.2 13.4	....	....	....
	300	217	12.6	....	....	....
Casein.......	80 to 100	368	14.9	50 to 100	360 to 552	14 5 to 22.4
	100 200	288 to 404	15.2 to 28.4	100 200	306 338	14.0 24.8
	200 250	284 344	17.9 26.6	200 250	341 347	18.4 18.7
	250 300	264 310	13.9 18.6	....	....	....
	300 350	321 337	20.2 21.2	....	....	....
Edestin......	100 to 200	373	21.0	90 to 100	336 to 395	16.5 to 21.9
	200 250	247 to 365	17.3 to 23.8	100 200	323 395	16.5 21.0
	250 300	252 321	11.7 19.1	200 250	265 349	14.8 21.8
	300 400	250 271	15.1 22.1	....	....	....
Milk proteins.	100 to 200	340	13.4	100 to 200	342 to 378	17.3 to 21.1
	200 300	283 to 302	14.9 to 22.1	....	....	....
	300 350	259 302	14.9 19.2	....	....	....
Gliadin......	250 to 300	241 to 308	23.4 to 27.2	90 to 200	304 to 375	19.0 to 27.0

Ranges of 7 to 15 milligrams of lactalbumin per gram of rat per week represent minima lower than those found for casein, edestin, milk proteins, or gliadin, not to mention the impossibility of maintenance with zein. With the pronounced individual variations in the total calorie intake it is impossible to make exact comparisons of rats of the same size on precisely the same intake of protein. It is an

obvious shortcoming of this method of procedure that the energy intake can not be controlled, for when this is large there may be a relatively great protein-sparing effect. Our results scarcely give any justification for the assumption that greatly increased energy intake will explain the lower values at which maintenance was secured with the lactalbumin food. It will be noted further that whereas maintenance could be secured very frequently with a lactalbumin content of less than 5 per cent in the diet, this was rarely the case with the other proteins. With all the foods, however, very small rats, naturally eating larger quantities of food per unit of body-weight, often attained maintenance (without growth) on lower protein intakes than sufficed for rats of larger size, *e. g.*, above 125 grams.

Speaking broadly, in the case of either edestin or casein, it has not been possible to obtain, with a protein intake of 12 to 15 milligrams per gram of rat, the degree of maintenance which is usually attained by feeding lactalbumin. For edestin and casein a correspondingly efficient intake seems to be about 20 milligrams in the form of the particular mixtures supplied. It is too early to make thoroughly satisfactory comparisons between the other proteins except to note that, comparatively, more gliadin was required. That this is not due to defective utilization in the alimentary tract in the case of any of these proteins has been demonstrated by direct analyses of the feces in many instances where a relatively high protein intake was found inadequate for perfect maintenance. The mixed proteins of cow's milk, as represented in our milk food, containing casein together with some lactalbumin, approach casein and edestin in value for maintenance, possibly being somewhat more efficient, as exemplified by a very slightly lower maintenance minimum figure. The higher figures for gliadin are in accord with its known exceptional character in respect to the yield of the various amino-acids characteristic of proteins.

Most of the food proteins are not so widely divergent in their general amino-acid make-up as to lead us to expect *wide* differences in the minimum amount of protein required for *maintenance*. In the case of *growth*, with its greater need of protein units, the divergences of the proteins may manifest themselves more conspicuously than in mere maintenance. The apparently greater efficiency of lactalbumin, in contrast with the other proteins recorded above, is in harmony with the observations of the apparent economy of this protein as a supplement to rations containing proteins deficient in one or more amino-acids. Numerous data now available in respect to growth have not yet been evaluated so as to permit exact statements regarding the comparative value of the proteins for this function.

These experiments, which have required a great deal of time and labor, have now yielded us a mass of data which was necessary before

we could develop a suitable method by which the relative value of different proteins, both for growth and maintenance, can be more precisely determined. Experiments already in progress indicate that it will be possible so to control the feeding that not only the absolute amount of food and protein eaten, but also the amount in relation to the body-weights of the animals, *i. e.*, milligrams of food per gram of body-weight, will be the same in all the comparable trials.

It remains to be determined how far differences in the metabolism of individual rats will affect the constancy of the results. Our experiments indicate that this factor will have small effect, except in rare cases.

The study of the efficiency of various fats in supplying certain nutrition-promoting properties to the diets of isolated foodstuffs upon which animals have been successfully grown has been continued. As predicted in our report for 1914, beef fat obtained from some of the abdominal tissues of the cow is not entirely devoid of the growth-promoting properties found in butter fat and certain other natural products. Our newer experiments have further shown that the failure of lard to promote growth in the same manner as do other natural fats (*i. e.*, butter fat, egg-yolk fat, cod-liver oil) is not attributable to deteriorating changes arising from heat or chemical agents in the commercial manufacture of the product. Heating butter fat with steam does not destroy its growth-promoting efficiency. Beef fat also renders the inefficient diets used by us more suitable for producing growth in rats than does lard. When butter fat and beef fat are subjected to fractional crystallization from alcohol, the growth-promoting factor remains in the mother liquor or "oil" fractions. The fractions containing fats with high melting-points are ineffective. The proportions of added "butter oil" and "beef oil" fractions selected were usually 6 per cent of the entire food, obviously representing a much larger addendum of the original fat. We have already shown that 6 per cent of cod-liver oil also is satisfactory for growth. In comparing the numerous records of growth on diets containing butter fat and beef fat, respectively, we have gained the impression already referred to, that butter fat is more effective in permitting growth than equivalent quantities of the beef fat. Recoveries are less prompt and prolonged growth is less satisfactory when the latter is used. In this connection it may be observed that the yield of the liquid "oil" fraction from butter fat is considerably larger than that from beef fat. The findings in respect to the beef fat explain the fact, which we have observed, that commercial oleomargarine also effects recovery in rats that have declined on the lard diets.

In evidence of the advantageous composition of the mixtures of isolated foodstuffs which we have employed in recent years in our studies on nutrition, we can now refer to records of albino rats which

have lived for two years or more upon such rations which have included a single added protein. Furthermore, animals have been bred and reared into the fourth generation on the same type of diet, having in general the following composition:

	Per cent.
Protein, e. g. edestin	18
"Protein-free milk"	28
Starch	24
Butter fat	18
Lard	12

Although our published experiments have afforded results which disprove the widespread view that the capacity to grow, or the growth impulse, is lost with age independently of whether it has or has not functioned during the period usually associated with increase in size, a number of questions relating to the persistence of the growth impulse remain unsolved. Thus, although it might be admitted that brief periods of inhibition of growth were without detriment to the animal, it has been stated that animals in which growth has been suppressed for a *very long* period can never reach the full size and physical equipment characteristic of unretarded individuals, although they may show some resumption of growth when suitable diet is furnished.

Again the question has been raised as to whether the age at which suppression of growth begins determines in any way the future outcome of the capacity to grow. Our records now show numerous prompt responses to the opportunity to complete growth at all ages, even when the retardation has been brought about long before the period of sexual maturity is reached. We now have records of resumption of growth in a number of animals which were stunted for more than 500 days—twice the age at which full size is ordinarily reached by the normally developing individual in the same environment. We can further say that the procreative functions are not necessarily impaired by stunting before the age at which breeding is ordinarily possible.

The results of our experiments up to date in the retardation of growth in animals may be summarized as follows: the growth impulse, or capacity to grow, can be retained and exercised at periods far beyond the age at which growth ordinarily ceases. In the case of our experimental animals, albino rats, in which increment of body-weight ordinarily ceases before the age of 300 days, resumption and completion of growth was readily obtained at an age of more than 550 days. It is now reasonable to ask whether the capacity to grow can ever be lost under these conditions unless it is exercised. Even after *very prolonged* periods of suppression of growth, the animals can subsequently reach the full size characteristic of their species. In this respect there is no impairment of the individual. The satisfactory resumption of growth can be attained not only after stunting by underfeeding, but also after the cessation of growth which results when the diet contains

proteins unsuitable for the synthetic processes of growth, or is low in protein. Growth in the cases referred to is resumed at a rate normal for the size of the animal at the time. It need not be slow, and may actually exceed the usual progress.

The period of growth may be greatly prolonged by inadequacies in the diet so that growth becomes very slow without being completely inhibited. Though the time of reaching full size is thus greatly delayed, growth, as indicated by body-weight, can ultimately be completed even during the course of an enforced retardation.

The methods of partially retarding or completely suppressing growth are too varied and unlike to permit final answers as yet regarding the outcome of all of the procedures of inhibition for the subsequent welfare of the individual. Our observations apply to the effects upon size and a few other incidental features mentioned. Although it is doubtful whether the fundamental features will be altered, far-reaching dogmatic statements are scarcely justifiable until the experiments have been extended to include other factors and other animal species.

The experiments mentioned in our last report as being undertaken with some of the high-protein feeds which were designed to show the most economical combinations in which these can be used to furnish protein for both growth and maintenance have been in progress during the present year and are yielding results of interest. Work along these lines is being continued as rapidly as facilities admit and it is expected that before long we shall have sufficient data for our first publication on this subject.

An attempt to study the value of gelatin in nutrition yielded such results that we felt the need of a more precise knowledge of the amino-acids yielded by this peculiar protein before continuing them further. We have therefore devoted much time to an analysis of the products of hydrolysis of gelatin and incidentally have obtained much information respecting the shortcomings of the methods available for determining the amount of the various amino-acids yielded by boiling proteins with strong acids. It is hoped that the experience thus gained may lead to improvements in the methods whereby the results may be more nearly quantitative than in the past.

The preparation of large quantities of "protein-free milk" used in our feeding experiments has given us an opportunity to study a number of substances which are present in milk in very small proportions, but which may have much more importance in nutrition than has heretofore been assumed. Whether milk contains lecithin or similar phosphatides has long been discussed, but no satisfactory evidence on either side has been set forth. We have been able to settle this question finally, by isolating from the alcohol washings of lactalbumin relatively large quantities of two different phosphatides. One of these is a monaminophosphatide containing nitrogen and phosphorus

in the ratio of 1 : 1; the other is a diaminophosphatide containing nitrogen and phosphorus in the ratio of 2 : 1. The former is similar to the lecithin obtained from egg-yolk and yields on hydrolysis glycerophosphoric acid, choline, amino nitrogen, and two or more fatty acids. The other resembles diaminophosphatides obtained from kidneys and other sources, but as yet we have not had opportunity to determine its products of hydrolysis.

A protein soluble in warm 70 per cent alcohol has been obtained from the alcohol washings of casein. This has been the subject of considerable study during the past year, but much further work is planned before the results will be ready for publication. This protein is apparently not derived from casein through changes incident to the processes employed in separating it from the milk, for the anaphylaxis tests made by Professor H. G. Wells showed that, while it possessed marked anaphylactogenic properties, it neither sensitized guinea-pigs to casein nor intoxicated those sensitized with casein.

A careful estimation of phosphorus made on 44 grams of "butter oil" yielded only 0.266 milligram of phosphorus or 0.0006 per cent. Since the less efficient butter fat has been shown to contain somewhat more phosphorus than this, we can conclude that the growth-promoting constituent of butter fat is free from phosphorus. It also appears to be free from nitrogen, since only minute traces of this element can be detected in the butter fat.

A study of the anaphylactic reaction with preparations of the so-called "proteoses" from various seeds has been made in cooperation with Professor H. G. Wells. The results obtained showed that these proteins, which have heretofore been assigned to the group of proteoses on account of their solubility in water and non-coagulability by heat, in reality belong to a new group which up to the present time has not been found in animal tissues. This is shown by the fact that they exhibit strong anaphylactogenic properties, whereas the proteoses obtained from native proteins by hydrolysis with enzymes, or by chemical agents, do not. It was also shown that individual proteins obtained from the extracts of many seeds can be so perfectly separated from one another that contamination of the preparations by the other proteins of the seed can not be detected by this delicate reaction. These results demonstrate that the specificity of the anaphylaxis reaction is determined by the chemical constitution of the protein, and not by its biological origin.

PALEOGRAPHY.

Loew, E. A., Oxford, England. *Continuation and completion of researches and publication of the "Scriptura Beneventana."* (For previous reports see Year Books Nos. 9-13.)

The outbreak of the European war found me in France, where I had just begun to make a transcript of the celebrated Bobbio missal, mention of which was made in my previous report. The manuscript is preserved in the Bibliothèque Nationale of Paris, and it was my intention therefore to stay in Paris long enough to make a careful study of all those points requiring examination of the original. Owing to the very unsettled conditions then prevailing, this plan was abandoned. I returned to Oxford, where I stayed and continued my work until May 1915. The war is also responsible for two other disappointing changes of plan. My Würzburg studies had to be shelved, since their continuation depended upon a second visit to Würzburg. The collection of plates supplementing my book on the Beneventan script was to have been published by the Clarendon Press some time during the current year; but owing to the fact that the sale of this costly collection would have been confined to the large European libraries, it was naturally decided to wait for more propitious times.

The major portion of the year was spent in work on the Bobbio missal. A transcript of its 600 pages, some of them almost undecipherable, accompanied by paleographical notes, was sent to the printer before I left Oxford. Although it is one of the oldest and most interesting liturgical books in our possession, liturgiologists are puzzled as to its origin; nor has the student of Romance languages been more fortunate in locating its home. The barbarous spelling in which the scribe indulges, as well as the additions entered on blank pages in low Latin, render this volume a rich mine of vulgar Latin and early Romance forms. It remains to be seen what light may be obtained from the combined results of history, liturgy, philology, and paleography. Considerable time was also devoted to preparing a study on the famous biblical manuscript known as the Codex Bobbiensis (*k*) of the Gospels. Material has also been collected for an article on critical signs in Latin manuscripts.

In the autumn of 1914 four lectures were given at Cambridge. During these visits I took the opportunity of examining manuscripts in the University Library, in Trinity Hall, and in the libraries of Corpus Christi, Pembroke, and Trinity Colleges. During the spring vacation I worked at the British Museum. After reaching America in June, I had the privilege of visiting J. P. Morgan's library. My attention was particularly drawn to the two oldest manuscripts of this splendid collection. Photographs of these were furnished me and permission given to publish the results of my observations. The lectures on old

English charters given at Oxford during the winter have brought me into closer contact with the problems of the Anglo-Saxon script, with which I was first confronted in my study of Würzburg manuscripts. The study of this script is the next large task to which I propose to devote my attention.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. *Study of the vertebrate fauna and paleogeography of North America in the Permian period, with especial reference to world relations.* (For previous reports see Year Books Nos. 2, 4, 8–13.)

Work for the last year has been largely directed toward the accumulation of material and data bearing on the paleogeography of the Permian and Permo-Carboniferous periods, and the environmental and other directive influences affecting the evolution of vertebrates at the close of the Paleozoic. This work will be continued in anticipation of a comprehensive treatment of the evolution of the late Paleozoic vertebrate fauna of the earth, similar to the work that has already been done upon that of North America.

A short field season in New Brunswick, Nova Scotia, and Prince Edward Island permitted an examination of the Permian or Permo-Carboniferous beds with regard to their relation to the beds of equal age in the United States and to the adjacent beds above and below them. On Prince Edward Island a small fragment of bone was found in a conglomerate at Cape Traverse; this is the second specimen of a fossil vertebrate found in the island and is with little doubt the proximal end of the humerus of a small Dimetrodon-like animal, confirming the reference of the rocks of the island to the Permian or Permo-Carboniferous. The character of the Red Beds was found to be, so far as the preliminary examination went, similar to those of the southwestern part of the United States, both in composition and structure, indicating similar conditions of deposition.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia. *Investigation of the vertebrate paleontology of the Pleistocene epoch.* (For previous reports see Year Books Nos. 11–13.)

During the past year the writer has been engaged in collecting information about the geology of the Pleistocene and its vertebrate animals. Two papers have been published, which contain some of the results secured. The titles of these will be found on page 34.

The greater part of the months of November, December, and January was spent in examining collections of Pleistocene materials in the possession of various institutions and of private individuals in the Western and Southern States. A part of a day was spent at Big Bone Lick, a locality made famous by the great quantities of fossil bones which have been collected there. Many collections were seen

in the cities of Colorado along the Front Range. In Texas many interesting specimens were studied. At Baylor University was found the skull of Nothrotherium, an edentate genus, found originally in South America, but known to occur also in caves and asphalt pits in California. At College Station, Texas, the large collection of Pleistocene vertebrates made by Dr. Mark Francis was studied; also the collection at the State University of Texas, at Austin, which contains many types of Cope's species. Valuable materials were seen at two institutions in New Orleans. The vertebrate collection of the Florida Geological Survey has been turned over to the writer for study. An unexpected amount of vertebrate remains was found in the Museum at Charleston, South Carolina, and the use of this has been secured. Evidence was obtained of the existence there, probably during some cold stage of the Pleistocene, of a moose closely related to the Canadian species. Incidentally, it was found that during the Miocene the three-toed horse *Parahippus*, not hitherto found east of the Great Plains, lived along the Atlantic Coast. As a result of the trip several new species have come to light and our knowledge of the distribution of others has been increased.

The months since January have been spent in studying materials obtained on the trip mentioned and other materials sent from various parts of the country.

Wieland, G. R., Yale University, New Haven, Connecticut. *Continuation of investigations on fossil cycads.* (For previous reports see Year Books Nos. 2–4, 6–9, 11–13.)

The text of the memoir on the Mexican Liassic Flora, prepared several years ago, has been printed by the Mexican Geological Survey and the plates also are ready; but owing to conditions in Mexico this work has thus far failed of binding and distribution. If finally necessary, an adequately illustrated abstract will be prepared for publication in English, the memoir being in Spanish.

Considerable progress has been made in studies of the anatomy of Cycadeoidean wood. These studies are limited to the best silicified trunks in order to clearly show that, aside from specialized features, the Cycadeoids have essentially the same wood structure as that of the more tree-like gymnosperms. In particular, the *Cycadeoidea dacotensis* (figured on plate VI, phot. 8, of Vol. I, American Fossil Cycads, and considered the finest stem among 800 Yale specimens) is being sawed through longitudinally and transversely with the object of cutting the thin sections from definitely located serial positions. The wedges cut from a few other less conspicuous but equally well-conserved American and foreign trunks are likewise receiving study. The urgently required field work in the mid-Mesozoic terranes already planned can not be begun before the new year.

PHILOLOGY.

Churchill, William, Philadelphia, Pennsylvania. *Research associate in primitive philology.*

In submitting this report upon activities under the grant for research in primitive philology it has seemed advisable to review the preliminary employment of the material upon which the present investigation is based, to note summarily the results which have been attained, to prepare the way for the forecast of the objects now within view.

The material available comprises a large mass of stories, poems, genealogies, and the like, literary material from Samoa, all collected by myself at different periods from the lips of the most wise elders of that people. In translating this material from the Samoan into English I found myself beset by the obstacle that no satisfactory dictionary of the Samoan language was in existence. To overcome this difficulty I set about the preparation of such a dictionary and made a beginning by a collation of the Samoan Scriptures, which now exists on index cards to the number of some hundred thousand. In the course of this work it became evident that a dictionary could not be written until the grammar of the language had been studied out, a theme which had not suggested itself to the missionaries to whose endeavors we owe such scanty material as to the language as is available.

In the study of the grammar of the Samoan, regarded as central in all the languages of Polynesia, it was soon found that the study of the syntax depended upon the more elementary study of the construction of the words employed in Polynesian speech. I refrained for many years from publishing the conclusions to which I was led, for I soon found that I was running counter to conclusions already pronounced by distinguished leaders in every school of philology. At the outset I found it necessary to revise the classification of these languages and to overthrow the Malayo-Polynesian speech family erected upon insufficient material by Bopp. In the next place it was found to be impossible to interpret these languages as agglutinative, and for that reason I was obliged to devote considerable attention to the establishment of the speech of this Pacific area and of immediately proximate islands as among the languages of isolation.

The earliest period of my production concerning these points is represented by contributions to transactions of learned societies and other scientific media of publication. Of these I note the following:

Principles of Samoan Word Composition. (Journal of the Polynesian Society, vol. xiv, 1905.)

Duplication Mechanics in Samoan and their Functional Values. (American Journal of Philology, vol. xxix, 34.)

Duplication by Dissimilation. (American Journal of Philology, vol. xxx, 171.)

Samoan Phonetics in the Broader Relation. (Journal of the Polynesian Society, vol. xvii, 79.)

Root Reducibility in Polynesian. (American Journal of Philology, vol. xvii, 369.)

Taken together, these several essays form the prolegomenon to the major work which has been published by the Carnegie Institution prior to this special grant. These works may be cited as follows:

The Polynesian Wanderings: Tracks of the Migration deduced from an Examination of the Proto-Samoan Content of Efaté and other Languages of Melanesia. (Publication No. 134.)
Beach-la-Mar: the Jargon or Trade Speech of the Western Pacific. (Publication No. 154.)
Easter Island: the Rapanui Speech and the Peopling of Southeast Polynesia. (Publication No. 174.)
The Subanu: Studies of a Sub-Visayan Mountain Folk of Mindanao. (Publication No. 184.)

In the "Polynesian Wanderings" the linguistic material was employed for the establishment of the migration of the Polynesian peoples from Indonesia and into their present home in the central and eastern Pacific, through the chain of islands stretching from New Guinea to New Caledonia, which constitute a geographical province to which has been assigned the designation Melanesia. In this work it was established that two distinct streams of migration, widely sundered in years, effected settlement upon Samoa and other islands of central or as, for purposes of this inquiry, I have designated it, Nuclear, Polynesia. To the older stream I have applied the distinctive name of Proto-Samoan migration; to the later stream I have drawn from the resources of Samoan history the designation Tongafiti migration. At present we lack information as to the origin in Indonesia and as to the various ports of call touched at by the Tongafiti people, and our account of their migration begins with their appearance in Samoa as oppressors of the people of their own race already seated there.

The migration stream of the Proto-Samoans is led out with considerable precision by the study of the languages of Melanesia as retaining inclusions or loan material taken from the Polynesians who have passed along that course. We find it to consist of two streams preserving their individual entity through this wide stretch of island-studded sea and nowhere coming into contact until by devious channels they reach Samoa. One of these, to which I have given the designation Samoa Stream, appears to have issued from Indonesia along the northern coast of New Guinea, eventually to have followed down the chain of the Solomon Islands, and thence to have leaped the long stretch of sea to Samoa. Between New Guinea and the Solomon Islands I was led by material then available to postulate the transit of the Samoa Stream through the Bismarck Archipelago and probably by the way of St. George's Channel. Captain Georg Friederici has pointed out, and supported brilliantly by later-won material, the possibility that an exit was made through the Dampier-Vitiaz Straits between New Guinea and the western end of the Bismarck Archipelago. This eminent authority employed his material to deny the existence of the St. George's Channel exit, but I am by no means convinced of the validity of this conclusion, while at the same time quite willing to admit the possibility

of the use of the Dampier-Vitiaz exit. The second course of migration, which I have designated the Viti Stream, appears to have issued from Indonesia by the Arafura Sea and Torres Straits along the south coast of New Guinea, thence parallel but in no sense interlacing with the Samoa Stream west of the Solomon Islands and coming again to land in the Banks Group and other islands of the northern and central New Hebrides Archipelago, thence to Fiji, and eventually rejoining the sundered members of their own family in Samoa.

The study of the Beach-la-Mar, so far as concerns the linguistic problems arising for solution, is devoted to the establishment of the parts of speech which we are to regard as fundamental in the Polynesian languages. These parts of speech are but three: the attributive, in which are included all those vocables which in all languages of higher development are known as nouns, verbs, adjectives, and adverbs; the demonstrative, which includes the article, the pronouns, and certain of the primitive adverbs of time and place and in an obscure degree of manner; the third, and for purposes of examination and grammar growth the most interesting, is the paradeictic, in which is included the germ element of the preposition and the conjunction.

The Easter Island volume is purely devoted to a study of the extent and manner of the mixture of Tongafiti and Proto-Samoan in the present speech of Samoa and Nuclear Polynesia.

The study of the greater problem in the development of the major project is almost wholly devoted to the examination of the speech material common to Indonesia and Polynesia. Employing this material in application to the problem of the position of Polynesian speech in systematic philology, I have, in the Subanu volume, presented all the arguments for the abolition of Bopp's Malayo-Polynesian speech family. I have, furthermore, completed the proof that Polynesian is an isolating speech and on that account can not be associated in any wise with the agglutinant languages of Indonesia. These initial and explanatory chapters of the present inquiry will be concluded by the examination of the Sissano speech of the northern coast of New Guinea, which, at the time of the submission of this report, is far advanced toward publication. The material thence derived is employed for the more definite determination of the movement of Proto-Samoan migration through New Guinea and the Bismarck Archipelago, and in that point particular attention will be directed toward the relative importance of the Dampier-Vitiaz Straits and St. George's Channel exits.

In all this preliminary work particular attention and careful study have been directed upon the character of Polynesian inclusions or loan material in Melanesia. It is interesting to observe that another inquirer, working with a wholly different object in view, and employing distinct materials in social life, has discovered in this same Melanesian area a ready and direct avenue to the study of the evolution of human society at what must appear to be its cradle stage. I refer in

this to the work of Dr. W. H. R. Rivers, of Cambridge University, whose two volumes, "The History of Melanesian Society," have but lately issued from the press. This independent evidence confirms me in my opinion that the Melanesian people present to us the picture of a race who have but recently, and as yet but imperfectly, acquired the employment of the consonants in the distinguishing of human speech from the animal cry. The development of this hypothesis has been progressive through my work as already presented in the foregoing tabulations. In my paper on "Root Reducibility in Polynesian" I set forth, in preliminary statement, as among the objects of these researches, the establishment of the principle that human consonantal speech evolves from the non-human animal cry by the employment of consonantal modulants with coefficient value. This principle becomes more and more clear as the work progresses and it is quite justifiable to express the assurance that the completion of these studies will establish it beyond peradventure. It therefore appears that this group of languages in the South Pacific is to yield us the chapter of the evolution of human speech seated in its proper place in the history of the evolution of man.

At this point it is eminently proper to restate the hypothesis to the determination of which the remainder of this work will, with more and more singleness of attention, be directed. I repeat the statement as made in "Root Reducibility in Polynesian," page 386:

Now we shall sum up our notes upon this group of roots:

ta the non-ego and the not-here reached by action outward, and probably downward.
va refers to that which intervenes between the ego and the not-here.
ga gives a limit of the extent of the not-here, a reduction of its distance or degree.
pa the beginning in the ego of action in the direction of the not-here.
ka makes plain that the not-here is not the ego but something external and therefore adversative.
ma joins the ego and the not-here with a link.
sa a general statement of the non-ego and the not-here.
na a particular statement of the non-ego and the not-here.
la a highly particularized statement of the non-ego and the not-here.

If we could master our problems of philology as we do those of algebra we should see a common factor in each member of this table. On the one side **a** is the greatest common divisor; on the other is that factor which we have uniformly traced to be that which is non-ego, not-here, not-now, three which are in essence one, the distal as contrasted with the proximal, the peripheral in contradistinction to the central. We should further see that as this consistent primary intonation of the voice was modulated by introductory closures of the organs of speech we obtained certain limitations of definitions of the peripheral sense of the primary vowel, and we might be led to regard the initial consonants as in some sort coefficients and to make to each one the provisional assignment of some germ of speech. Further to deal with this series of consonantal meanings as coefficients of this and other vowels, having the value of determinants of space and in such other senses as we may prove them to possess, would require us to pass in review the whole of Polynesian speech, the Samoan and its near kin and its more remote congeners in the

island world. Within the limits of such an introductory paper as this it must suffice to say that the investigation has been pushed with uniformly confirmatory results for the several phonetic elements of the Samoan, and that close comparative dissection of many groups of Polynesian is yielding wonderful results along the line just indicated.

Having cited the "Cratylus" it will be impossible to avoid the comparison with the childish linguistic guesses which Plato puts into the mouth of Socrates, the ρ of motion, the shaking, agitating, swelling ϕ, ψ, σ, ζ; the binding, resting δ and τ, the smooth and gliding λ. The results of many years investigation of Polynesian speech point more and more distinctly all the time to such possibilities as Plato seems dimly to have foreseen.

In this series of roots to which attention has been at such length directed we have accumulated one general sense, the non-ego under certain relations, the nature of such relations varying with the consonantal coefficient.

There yet remains to us to investigate the naked vowel **a** devoid of all coefficients, the primary and unmodulated sound of lungs and larynx regarded solely as a reed instrument of the type of soft-walled resonator. To accord with the scheme which we have seen to develop in the examination of its modulated variants this **a**, when absolute, should express, so far as is possible for the human mind in any early plane of progress to conceive the abstract, the sense of the non-ego and the not-here and the not-now. We need not fear to assign the capacity of the abstract to a primitive people of so elemental a type as the Proto-Samoan. In that formative stage the object to which the name is to be applied is most narrowly concrete, none the less it is plain that the name that is applied to that object is a diffuse abstract, the expression of some quality which may serve to assist the identification made primarily by the indicative finger. Thus so general a statement as our *çru-kan* identifies the sweet singing bird and we find it in its *rossignol* shape serving for nightingale, song sparrow, and mocking bird. "And he called their name Adam in the day when they were created," nothing could be more concrete than the one man of Paradise, the one man of all the world, yet the Talmudic gloss shows the name to be so abstract a quality as redness. . . .

Thus we have completed the cycle of the Samoan roots in this **a** and we have shown the greatest common divisor of the series to consist of the essential idea of the naked **a**. Roots of other series have been in this research worked out along parallell ines to a similar result. Even the apparently closed roots, where sufficient have been identified to form a series, show that the same principle is operative. Is it, then, too much to claim for our Polynesian that it offers us something infinitely more primitive than the root in linguistics? Call it seed if it be worth while to preserve the classic imagery of the stem and the root. The name is of no moment; it is momentous that the Polynesian is being made to yield to philology forms of speech so embryonic that by them we can place ourselves at a point where the near vision must yield us the view of a speech in the making, even if not the genesis of speech itself.

As speech is the means of the expression of a thought which precedes the physical fact of utterance, we shall find the one conditioning the other, philology and psychology interacting in every earliest stage of speech development to comprehension of which we may attain. The delver after philological origins must call upon the psychologist for a better understanding of the diffuse and nebulous word meanings to which he is irresistibly led, and in the same measure these expressions of the most primitive concepts in turn prove instructive to the student of the psychology of the infancy of mankind. These researches into the Polynesian, therefore, may be expected to possess for the psychologist an interest second only to that which they have for the special student of speech.

This examination of the vocal equipment of the beginning speakers of Melanesia shows that the three speech organs of the buccal cavity are employed with varying degrees of precision and facility. We find that the first appearance of consonants modulating merely animal vowels lies in the region which in our alphabetical tables we designate as the liquid; in this group we find three consonants, **L** and two types of **R**; some of these languages have arrived at facility in the use of **L** only, others employ one or both of the **R** types, few employ all three. The next step in advance consists in the employment of the nasal consonants, **NG**, and **N** and **M**, with interchange, or more properly mutation, between each of these primitive consonants and its neighbor in the series; there is further an interchange between the **L-R**, and the **N** of the nasal series, both of these groups being produced in practically the same central area of the buccal cavity.

The next step of progress consists in the employment of the consonants producible by the palate. At this point we encounter a distinct principle of mutation which runs through all of the languages involved in this study, namely, that mutation is confined to the consonants produced by any one of the three speech-organs and does not pass from any one speech-organ to another. We further find that the earliest employment of the consonant possibility is confined to the simplest and to the most forceful use of the speech-organ involved, thus establishing the terminal points long before the medial positions which later on are to intervene have become established (Easter Island, page 18). Thus in the case of the palatal consonants we find a direct leap from the nasal **NG** to the mute at the opposite extreme, either surd **K** or sonant **G**. As the intervening sounds become established in the palatal series we find that these beginning speakers have acquired terminal points of the lingual series represented by **S** and **T** respectively. Scarcely one of the languages of Melanesia has acquired such facility in the use of the lips in speech as to enable them to pronounce even the simplest of the labial consonants with certainty of enunciation.

In this connection it is important to observe that comparative anatomists, in their study of skeletal remains of the man of the interglacial periods, have advanced the expression of the opinion that the Neanderthal man and others of that epoch, as well as the Piltdown skull (upon which has been erected the genus *Eoanthropus*), were lacking in ability to employ consonants in speech and therefore were lacking in what might be called true human speech. This opinion is based upon study of the lower mandible and particularly of the point of attachment of the genioglossal muscle. In effect, their contention is that the genioglossal muscle of mankind of this primitive type of evolution was insufficient for the control of the central organs of speech, the tongue wholly and the palate to a less distinct degree. It happens that the only undisputed point of the Piltdown skull is the lower mandible, and this point of the speechlessness of the aboriginal woman of Great

Britain to whom this skull once belonged is the only point upon which the schools of interpretation are in agreement. It is evident that the determination has been made by the students of comparative anatomy without employing the assistance of those who have made particular examination of the use of the genioglossal muscle in human speech. We are not in a position to traverse the conclusions of the comparative anatomists in this matter, nor are we prepared to accept their conclusions so far as they apply to problems of linguistics. It is therefore respectfully submitted that this is one of the minor problems of linguistics which might properly be studied by the comparative anatomist and the comparative philologist in collaboration, to the final determination of what the facts of the case really are.

We now pass to the examination of the material, specifically Samoan, upon which we are to base our succeeding researches into a beginning of the speech of man. At this point we are to accept as established the dissolution of Bopp's Malayo-Polynesian speech family, the establishment of a syntax and art of language based upon three parts of speech, the validity of the Polynesian inclusions and loan material in Melanesia as establishing the earliest type of Proto-Samoan speech. Accepting these as established, we are to continue the remainder of the examination on distinctly Samoan material in the manuscripts which I have taken down from the speech and dictation of wise Samoans. I find myself in possession of several hundred thousand words of matter which now for the first time may be brought under literary and linguistic examination.

An initial chapter in this manuscript material consists of genealogies of Samoan families of distinction, some of which begin in a period anterior to the creation of the world and extend in uninterrupted succession to the present time, others begin more properly within the historic period and follow the line of descent to men and women now living. Yet others overlap at this or at that point of the rearward generations and lend confirmation each to each. The linguistic value of these genealogies is insignificant, but they occupy a very important position in establishing the traditions and myths of the Samoan people in such wise that it may be possible to synchronize them with the Christian era of our own time-reckoning. The work will be intricate, but we have sufficient material to enable us to synchronize different tables of descent and thus establish here and there definite epochs of culture development to which the history of the people may be correlated. Furthermore, we are now able to draw upon genealogical tables in other and distant branches of the Polynesian race, whereby we may obtain greater accuracy in determining the critical points of their history. These different genealogical tables need elaboration and synchronization in order that they may be employed in the editing of the corpus of myth and tradition which will yield rich material, when properly understood, for the dictionary.

The collection of myth and tradition constitutes the body of the social history of the Samoans. We have records of the creation of the world, we have tales of heroes derived from an age of fable, we are able to distinguish the beginning of real history, and we are able to identify the course of events during the more modern period which will prove of distinct historical value. These traditions, never before published, scarcely even known to be in existence, will yield a rich supply of words to be set into the dictionary and thus to become available for the purpose of this special linguistic study.

The third important group of manuscript material consists in courtesy phrases arranged by the units of Samoan social life, the hamlet and the district as made up of a group of associated hamlets. This amounts in Samoan life to a social register, in effect to a "Who's Who in Savagery"; it is known as the *fa'alupega;* it is absolutely essential to intercourse with the Samoan upon the terms of gentility and courtesy which so strictly characterize their life. It is rich in linguistic material, and it is absolutely essential to the proper ordering of the genealogical material and to the proper comprehension of the traditions and historical matters.

This material must be edited and brought to print before it can be employed in its proper place in the dictionary. This dictionary, as the resultant of the study of the foregoing material, will in turn serve as the base whereupon we are to proceed to the examination of speech evolution at this focus of human development in the Pacific and immediately adjacent waters. It has already been mentioned that my manuscript dictionary contains a complete collation of every word employed in the Samoan version of the Scriptures. In addition, the alphabetical order of the dictionary cards contains all that has been published in the vocabularies of Samoan speech issued under the direction of the London Missionary Society. To this has been added a most extensive collation of the other languages of this family and all material available for the study of its comparative philology that may have been derived from the other languages of Melanesia and Indonesia.

In the course of elaborating this dictionary material for publication it would be necessary to work out the principles of Samoan grammar. It is, therefore, expected that the work upon the dictionary and the work upon the grammar will proceed with even steps and that they will advance to completion at practically the same time. It will be recognized that it would be inadvisable to employ merely the dictionary in the study of the beginning of this speech, and that the comparison of its grammar with the usage of other speech would be ineffective without the dictionary material. Therefore, it is manifest that these two chapters of one work must be dealt with as an indissoluble unit.

Accordingly, I sum briefly the work in prospect under this project of research in primitive philology. A certain considerable mass of

hitherto unknown Samoan material must be transcribed, must be edited, must be translated, must be fortified by every contribution from any source which can be brought to bear to enrich the narrative. When thus reduced to permanent form as an object in itself, it becomes available for the furtherance of this course of study. It must be incorporated point by point with the dictionary, now in a considerable stage of advancement. Its idiom must be studied, its usage must be codified, all this for the establishment of our correct comprehension of the grammar of the language. These two items, dictionary and grammar, become again a second foundation upon which we are to advance to the study of the position of this group of human languages relative to the broader theme of human speech in general, and thus to lead us to seize one of the most interesting problems of the development of man, the thinking animal, finding the expression of thought in that priceless possession of the group of consonants, no matter how scantily acquired, no matter how clumsily enunciated, which establishes his position as superior to the animal which can not speak and, therefore, which can but imperfectly convince us of its ability to think.

I have already mentioned the satisfaction which it has proved to me to find that Professor Rivers has been led through distinctly ethnological channels along the same Melanesian path toward the beginning of cultural and social advancement that my linguistic inquiries have established so solidly for me. If the Cambridge scholar and myself had had an intercommunication of views upon Melanesia this general confirmation of my opinion would have been lacking in cogency. That he has been a student of my "Polynesian Wanderings," however, is clearly evidenced by his comment in his recent work. While he does not accept my determination that the Tongafiti migration reached Samoa without having left its impress upon Melanesian speech—and this is a matter in which the ethnologist must accept the determination of the philological student—he expresses himself as interested in the many points of agreement of my conclusions with his own scheme of the ethnological interpretation of the position of the Polynesians in Melanesia. My investigation (in which the linguistic element is the supreme factor, yet in which my determinations must be conditioned by the factor of intimate personal acquaintance with the people under examination) leads me more and more surely to confidence in the belief that the Polynesian languages, assisted toward interpretation by the Melanesian material employed, lead us inevitably in the direction of a beginning of human speech.

I have used the expression "a beginning" advisedly. The question whether speech evolution has proceeded from a single center for all speaking men is one upon which none may yet venture to pass. It awaits decision based upon linguistic evidence which it is hoped that the future will offer to us, just as we may not yet assume to pass upon

the question whether the physical evolution of man has proceeded from a single center or from several foci in regions where climatic conditions have proved favorable to such advancement beyond the plane of merely brute life. I wish to suggest, for consideration in this matter, the further fact (already pointed out by Professor Rivers) that within the Melanesian area, wherever we find islands of sufficient magnitude to afford contrast, there is a marked difference between the people on the coast and the much ruder and less advanced inhabitants of the mountain regions within. This is known to be true of the great Fijian island, Viti Levu, where Rivers has made valuable employment of the cultural differences which he has found to exist. It is also, within my knowledge, true of the larger islands of the Solomon group, where the inland people of the mountains are distinctly lower in type, physically, than the coast dwellers. I extend the investigation somewhat further than has suggested itself to the distinguished Cambridge scholar. In the Malay seas we encounter several instances of the sort. In Mindanao, the Subanu are distinctly lower than their Visayan neighbors, both linguistically and culturally, and I interpret the record of my collaborator, Colonel Finley, to indicate their physical inferiority likewise. In Luzon we find as inferior and interior folk the Aeta and the Bontoc Igorot. In Borneo we likewise find the same inferiority to hold in the case of the Punan of the high mountain lands of the interior. In New Guinea it has been established by recent exploration, notably that of Wollaston in command of the expedition of the British Ornithological Union, that there exists a considerable population of nanoids, possibly to be classed with the pygmies. This dwarfish stature, characteristic in a greater or less degree of all these inferior peoples, deserves to be mentioned. I do not in the least suggest the interpretation of this characteristic of inferior peoples in terms of physical evolution. But I can not avoid the recognition of one important point, which may or may not be associable with the precarious existence down to the present time of so many nanoid peoples in this particular area of sea and island: It is in the same island region, at the Trinil beds in Java, that discovery was made of the skeletal remains upon which Du Bois has erected the genus and species *Pithecanthropus erectus*. If students of the physical evolution of man in time incline to recognize in the Trinil discovery the evidence of an Indonesian focus of evolution, then I shall be prepared to recognize in the same region a focus of the evolution of the speech of man. It is toward the preparation of the science of philology for this step, after the students of somatic anthropology have prepared the ground, that these studies of the philology of the peoples of the Pacific have been addressed.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Study of diffusion of gases through liquids and provision for applications of the elliptic interferometer.* (For previous reports see Year Books Nos. 4, 5, 7–13.)

During the course of the present year Professor Barus completed for the press the report referred to in the last volume, and it will be printed in September 1915. One interesting result of the application of the interferometer to the horizontal pendulum need only be mentioned here. In applying this method to the determination of an elongation due to any cause, it was found that increases of length of the order of 4×10^{-10} of the original length should fall within the range of measurement, so far as the method itself is concerned.

In the furtherance of new experiments Professor Barus has constructed a linear displacement interferometer, with the parts separately attached to a single wide pier and at a sufficient distance apart to admit of observation through tubular vessels up to 2 meters in length. The sensitiveness remains unchanged throughout. Apart from the increased availability of the apparatus for long vessels, it offers special advantages arising from the fact that the equations are simplified when the angle of incidence is zero and from the greater steadiness of the apparatus. It has in fact been possible to use it continuously in spite of the commotion surrounding the laboratory.

With the aid of the new interferometer, methods worked out in the earlier report were repeated under better conditions. Thus measurements were made at some length on the refraction of air at high temperatures, on the dispersion of air under various interesting conditions, on the effect of the intense ionization on the refraction of air, etc. Moreover, the method for studying the adiabatic expansion of air was further developed and the specific coefficients were obtained for tubes 1, 2, and 4 inches in diameter.

In all cases of displacement interferometry a difficulty is encountered, inasmuch as the method of measuring in terms of displacement is somewhat less sensitive than the method of counting interference rings or fringes. The latter course lies equally within the scope of the displacement method; but it is the distinguishing feature of the latter that the ellipses may always be found and brought back to the fiducial position, however sudden or extensive the phenomenon of displacement. The method, in other words, is without break.

The sensitiveness of the displacement interferometer may be increased indefinitely by equalizing the component air-paths and glass-paths respectively (*i. e.*, reducing the path-difference to zero in each case), but the ellipses at the same time enlarge and grow too diffuse for use in measurement. Professor Barus has therefore sought to remedy this by the use of curved compensators, lens-shaped bodies by

which the conjugate interference paths of the successive rays of a pencil of light may be modified systematically. Though the work is not yet completed, the experiments made thus far have been very favorable, the whole object being to obtain interference patterns sufficiently cramped to be available for adjustment. Incidentally, the frequent transitions of elliptic into hyperbolic types of interference between the extreme cases of horizontal and vertical lines are interesting theoretical results.

Finally Professor Barus has succeeded in obtaining what appears to be a very interesting and new departure in optics, viz, forced vibrations, exhibited by light waves of slightly different wave-lengths.

Hayford, John F., Northwestern University, Evanston, Illinois. *Investigation of the laws of evaporation and stream flow.* (For previous reports see Year Books Nos. 12 and 13.)

The primary purpose of this investigation is to determine the amount, and the relation to meteorological conditions, of the daily evaporation from a large free-water surface, such as a lake or a large reservoir. In using any one of the Great Lakes for this purpose it is necessary to evaluate the income to the lake from all sources, the outgo, and the change of content of the lake, day by day. The change of content becomes known if the change in the mean-level of the whole lake surface is ascertained. The most serious difficulties encountered in determining the change in the mean-level of the whole lake surface are those which arise from the fact that changes in the barometric gradients over the lake, and changes in direction and velocity of the wind, produce fluctuations in the level of the water-surface at the gage which is the station of observation. One must first evaluate these local changes of level with a high degree of accuracy before it is possible to determine the outgo in the form of evaporation. During the year just ended, attention has been concentrated largely upon this phase of the problem, with steadily increasing success. The knowledge which is thus being secured of the laws of the barometric effects and wind effects bids fair to be of considerable value. Each one of the four Great Lakes is being used separately in the investigation. Important checks against erroneous conclusions are thus obtained.

At first it was believed to be sufficient for the purpose of the investigation to compute the mean barometric gradients for each day over the lake concerned, and to determine by the proper least-squares computations the effect upon the water-level at the gage of the change from day to day in this mean gradient. It has been found, however, that in order to express the phenomena adequately one must take account of the changes in barometric gradients in each successive 12-hour period. Also, it has been found that at least 8 constants must be determined to express the barometric effects at a station adequately,

whereas it was originally assumed that but 2 constants were desirable. Similarly, it was at first assumed that one might express the wind-effects sufficiently well in terms of the mean velocity and prevailing direction of the wind for each 24-hour period. The investigation to date indicates that it is necessary to take into account the wind velocity and direction for each hour, and that possibly at least 8 constants are necessary to express the effects adequately, instead of 4 constants as at first assumed.

The data, including nearly all necessary meteorological observations, are in hand for the equivalent of 223 months of observations of the lake surface at one gage. Of these 223 months of observations, but 107 have yet been used in the computations, and even for these months it is now known that considerable improvements are possible in the method of computation thus far used. Hence, much more progress is possible in the investigation. It is now reasonably certain that the evaporation under prevailing conditions will be determined with a probable error not greater than one-fifth of the evaporation.

No serious attempt has thus far been made to study stream-flow, as that portion of the investigation is intended to be based on more information in regard to evaporation than is now available.

Howe, Henry M., Columbia University, New York, New York. *Investigation into the physics of the iron carbon alloys.* (For previous reports see Year Books Nos. 6–13.)

During the year 1914–15, most of the work has been done on the nature of the deformation lines in metals, and especially in alpha iron and gamma iron. The results will be published in a volume on the metallurgy of steel, about to go to press.

The following is a brief résumé of the lines of my investigations, with a statement of some of the facts educed:

1. The details of the appearance of slip bands in alpha and gamma iron and in copper, of Neumann bands in alpha iron, and of annealing twins.

2. The retardation of the Brinell hardness test greatly increases the apparent hardness of iron by giving an opportunity for the transformation incited by the earlier stages of the test to take effect, and to raise the elastic limit before the later stages occur.

3. The path of rupture in pure alpha iron and in mixtures of alpha iron and pearlite.

4. While the deformation in the early stages is in appreciable part intergranular—that is, between the polyhedral allotriomorphic crystals of which the metal is composed, commonly called grains—yet the path of rupture passes by preference as far as possible from the grain boundaries and therefore along grain centers. I have sought methods of explaining this phenomenon. The present evidence indicates that,

because of the dis-registry between the slip planes in adjoining grains, the propagation of slip across each of these boundaries de-crystallizes some of the metal there, and thus strengthens the boundary metal progressively, so that though before deformation the boundaries are paths of relatively low resistance, as deformation proceeds their resistance increases progressively, till it soon exceeds that of the grain bodies, with the result that rupture is trans-granular.

5. The pro-eutectoid ferrite and cementite which form in gamma iron in cooling through the transformation range are ejected to the exterior of the grains. The process is such as to indicate that the motive power for this ejection resides in the gamma iron itself and not in the nature of the boundaries between the various grains. Under proper conditions the whole surface of the mass becomes coated during the cooling down through the transformation range with the pro-eutectoid element. As such surfaces consist of random sections cut across these crystallographic grains, it is evidently not the surface that has attracted the pro-eutectoid element, but the gamma iron that has expelled it.

6. Experiments have been conducted on the formation of so-called ghosts or bands abnormally rich in ferrite, which are injurious to steel, and some of the conditions which bring about this ghost formation have been shown.

7. The hardening effect caused by cold deformation is very slight immediately after the deformation has occurred, but it increases both with time and with gentle heating to about 300°, showing that the effect of rest and heating, which had previously been known to apply to the elastic limit, applies also to the hardness.

8. In addition to confirming the results of previous observers, showing that the Neumann lamellæ or mechanical twins of alpha iron follow the 211 trapezohedron, I find evidence that they also follow cubic planes.

9. The slip planes in alpha iron, instead of being octahedral, as has hitherto been reported by various observers, follow these same planes of the 211 trapezohedron.

Lewis, E. P., University of California, Berkeley, California. *Photographic investigations of vacuum-tube spectra of gases and vapors.* (For previous reports see Year Books Nos. 3–7.)

The last report from me was made in 1908 (concerning the observations with the quartz spectrograph taken in the Crocker eclipse expedition in 1908). No call for a report has reached me in recent years, and until two years ago there has been nothing to report. Four years of close application to my duties as a member of the local board of education, followed by a year of sabbatical leave, made these years barren, for I had no trained assistant qualified to carry on the work under my

direction. About two years ago I was able to make a fresh beginning, and I inclose the titles of four articles published recently, and send copies of these articles under separate cover. I may add that I have nearly ready for publication articles on the ultra-violet spectra of krypton and xenon, and that R. L. Sebastian, working with me, is completing an article on the absorption spectra of the mono-derivatives of benzene, all this work having been accomplished with the quartz spectrograph secured with the aid of the grant. Reports on these researches were made at the meeting of the Physical Society held here August 5, 1915, and abstracts will shortly be published in the Physical Review.

Michelson, A. A., University of Chicago, Chicago, Illinois. *Ruling and performance of a ten-inch diffraction grating.* (For previous reports see Year Books Nos. 2 and 3.)

The principal element in the efficiency of any spectroscopic appliance is its resolving power—that is, the power to separate spectral lines. The limit of resolution is the ratio of the smallest difference of wave-length just discernible to the mean wave-length of the pair or group. If a prism can just separate or resolve the double yellow line of sodium its limit of resolution will be $\frac{5896-5890}{5893}$ or approximately 0.001, and the resolving power is called 1,000.

Until Fraunhofer (1821) showed that light could be analyzed into its constituent colors by diffraction gratings this analysis was effected by prisms, the resolving power of which has been gradually increased to about 30,000. This limit was equaled if not surpassed by the excellent gratings of Rutherford of New York, ruled by a diamond point on speculum metal, with something like 20,000 lines, with spacing of 500 to 1,000 lines to the millimeter. These were superseded by the superb gratings of Rowland, with something over 100,000 lines and with a resolving power of 150,000.

The theoretical resolving power of a grating is given, as was first shown by Lord Rayleigh, by the formula $R=mn$, in which n is the total number of lines and m is the order of the spectrum. An equivalent expression is furnished by $R = \frac{l}{\lambda}(\sin i + \sin \theta)$, where l is the total length of the ruled surface, λ the wave-length of the light, i the angle of incidence, and θ the angle of diffraction. The maximum resolving power which a grating can have is that corresponding to i and θ, each equal to 90°, which gives $R=\frac{2l}{\lambda}$; that is, twice the number of light-waves in the entire length of the ruled surface. This shows that neither the closeness of the rulings nor the total number determines this theoretical limit and emphasizes the importance of a large ruled space.

This theoretical limit can be reached, however, only on the condition of an extraordinary degree of accuracy in the spacing of the lines. Several methods for securing this degree of accuracy have been attempted, but none has proved as effective as the screw. This must be of uniform pitch throughout and the periodic errors must be extremely small. For a short screw, for example, one sufficient for a grating 2 inches in length, the problem is not very difficult, but as the length of the screw increases the difficulty increases in much more rapid proportion. It was solved by Rowland in something over two years.

Since this time many problems have arisen which demand a higher resolving power than even these gratings could furnish. Among these is the resolution of doubles and groups of lines whose complexity was unsuspected until revealed by the interferometer and amply verified by subsequent observations by the echelon and other methods.

Others that may be mentioned in this connection are the study of the distribution of intensities within the spectral "lines"; their broadening and displacement with temperature and pressure; the effect of magnetic and electric fields, and the measurement of motions in the line of sight, as revealed by corresponding displacement of the spectral lines in consequence of the Doppler effect. All of these have been attacked with considerable success by observations with the echelon, the interferometer, and the plane-parallel plate. These methods have a very high resolving power, but labor under the serious disadvantage that adjacent succeeding spectra overlap, making it difficult to interpret the results with certainty.

Some twelve years ago the construction of a ruling engine was undertaken with the hope of ruling gratings of 14 inches—for which a screw of something over 20 inches is necessary. This screw was cut in a specially corrected lathe, so that the original errors were not very large, and these were reduced by long attrition with very fine material until it was judged that the residual errors were sufficiently small to be automatically corrected during the process of ruling. The principal claim to novelty of treatment of the problem lies in the application of interference methods to the measurement and correction of these residual errors. For this purpose one of the interferometer mirrors is fixed to the grating carriage, while a standard, consisting of two mirrors at a fixed distance apart, is attached to an auxiliary carriage. When the adjustment is correct for the front surface of the standard, interference fringes appear. The grating carriage is now moved through the length of the standard (0.1 mm. if the periodic error is to be investigated; 10 or more millimeters if the error of run is to be determined) when the interference fringes appear on the rear surface. This operation is repeated, the difference from exact coincidence of the central (achromatic) fringe with a fiducial mark being measured at each step in tenths of a fringe (twentieths of a light-wave). As a whole fringe

corresponds to 0.00001 inch, the measurement is correct to within 0.000001 inch.

The corresponding correction for periodic errors is transferred to the worm-wheel which turns the screw, and for errors of run to the nut which moves the carriage. In this way the final errors have been almost completely eliminated and the resulting gratings have very nearly realized their theoretical efficiency.

A number of minor points may be mentioned which have contributed to the success of the undertaking:

(*a*) The ways which guide the grating carriage as well as those which control the motion of the ruling diamond must be very true; and these were straightened by application of an auto-collimating device which made the deviation from a straight line less than a second of arc.

(*b*) The friction of the grating carriage on the ways was diminished to about one-tenth of that due to the weight (which may amount to 20 to 40 pounds) by floating on mercury.

(*c*) The longitudinal motion of the screw was prevented by allowing its spherically rounded end to rest against an optically plane surface of diamond which could be adjusted normal to the axis of the screw.

(*d*) The screw was turned by a worm-wheel (instead of pawl and ratchet) which permits a simple and effective correction of the periodic errors of the screw throughout its whole length.

(*e*) A correcting device which eliminates periodic errors of higher orders.

(*f*) It may be added that the nut which actuates the carriage had bearing surfaces of soft metal (tin) instead of wood, as in preceding machines. It was not found necessary to unclamp the nut in bringing it back to the starting-point.

Finally it may be noted that instead of attempting to eliminate the errors of the screw by long-continued grinding (which inevitably leads to a rounding of the threads) it has been the main object to make these errors conveniently small; but especially to make them constant—for on this constancy depends the possibility of automatic correction.

Doubtless the possibility of ruling a perfect grating by means of the light-waves of a homogeneous source has occurred to many, and indeed this was one of the methods first attempted. It may still prove entirely feasible and is held in reserve if serious difficulty is encountered in an attempt now in progress to produce gratings of 20 inches or more. Such a method may be made partly or perhaps completely automatic, and would be independent of screws or other instrumental appliances.

It may be pointed out that an even simpler and more direct application of light-waves from a homogeneous source is theoretically possible and perhaps experimentally realizable. If a point source of such radiations send its light-waves to a collimating lens and the resulting plane-waves are reflected at normal incidence from a plane surface, stationary

waves will be set up, as in the Lippman plates; these will impress an inclined photographic plate with parallel lines, as in the experiment of Wiener, and the only limit to the resolving power of the resulting grating is that which depends on the degree of homogeneity of the light used. As some of the constituents of the radiations of mercury have been shown to be capable of interfering with difference of path of over 1,000,000 waves, such a grating would have a resolving power exceeding 1,000,000.

This investigation has had assistance from the Bache Fund of the National Academy of Sciences, from the Carnegie Institution of Washington, and from the University of Chicago.

In addition to the grateful acknowledgment to these institutions I would add my high appreciation of the faithful services rendered by Messrs. Julius Pearson and Fred Pearson.

Nichols, E. L., Cornell University, Ithaca, New York. *Systematic study of the properties of matter through a wide range of temperatures.* (For previous reports see Year Books Nos. 4–13.)

In continuing the study of the fluorescence absorption of the uranyl salts we have had a large number of new salts prepared by Mr. D. T. Wilber. All show fluorescence spectra of the same general type as those of the salts previously studied. While the investigation of the absorption of the new salts has not been completed, there is every indication that the absorption spectra also consist of series of bands whose different members are equally spaced on the frequency scale. The interval between bands appears to be constant for any given salt and has nearly the same value for all the uranyl compounds. The interval between absorption bands, however, is considerably shorter than the interval between the fluorescence bands of the same salt.

In the case of a large number of salts Mr. Wilber has found it possible to prepare crystals that are large enough for individual study. This has made possible an investigation of the influence of the plane of polarization of the incident rays upon their absorption and exciting power, and of the condition, as regards polarization, of the light emitted during fluorescence. The double chloride of uranyl and ammonium has shown itself particularly well suited to such an investigation, since the bands of absorption and fluorescence are surprisingly sharp, even at ordinary temperatures. The double salts of potassium, rubidium, and cæsium show the same characteristics.

A preliminary account of the results obtained has been published in the Proceedings of the National Academy (E. L. Nichols and H. L. Howes, vol. 1, p. 444, August 1915) and two more extended articles will shortly appear in the Physical Review. It is found that (1) each fluorescence band is plane-polarized; (2) when the carbon arc is used for excitation, the intensity and polarization of each fluorescence band

is independent of the condition, as regards polarization, of the exciting light; (3) the crystals are strongly dichroic, but the bands belonging to a given constant-interval series have the same plane of polarization.

In the case of uranyl nitrate an investigation has been made of the effect of water of crystallization upon the fluorescence and absorption spectra. This salt is well suited for such a study, since it can be made in the form of crystals containing respectively 2 and 3 molecules of water as well as in the more common form of the hexahydrate. The spectra of the different hydrated crystals are found to differ widely, both as regards the position of the principal bands and as regards the intervals between bands.

The study of the electrical properties of oxides carried on during the summer of 1913, and originally undertaken by Mr. A. A. Somerville, was continued during the year by Mr. C. C. Bidwell. The oxides thus far studied are those of cadmium, lead, and iron. When possible, simultaneous determinations have been made of the Hall effect, thermo-electric power, and electrical conductivity through a wide range of temperature.

In the case of lead oxide (PbO) the thermo-electric power lines indicate the existence of α, β, and γ modifications. The transformation temperatures are fairly definite and the changes are reversible. When PbO_2 was slowly heated in air the reduction to Pb_3O_4, which sets in sharply at about 280° C., is accompanied by profound changes in resistance and thermo-electric power, and at a temperature of about 550° C. a further reduction to PbO is made evident by marked changes in the properties studied. A polarization e. m. f. of approximately 1.7 volts was observed in PbO_2, and Pb_3O_4 was found to collect rapidly at the anode.

Both the non-magnetic iron oxide, Fe_2O_3, and the magnetic oxide, Fe_3O_4, were found to show a transformation point at about 780° C. The change is apparently related to the recalescence which takes place in pure iron at this temperature. Both oxides of iron show a variation of electrical resistance with temperature which is in close agreement with the relation predicted by the theory proposed by Königsberger.

The effect of high and low temperature upon the absorption of selenium glasses in the visible spectrum has been studied by Mr. K. S. Gibson. These glasses transmit mainly the light of longer wave-lengths. A rise in temperature produces a very marked decrease in transmission of these longer wave-lengths in such a way as to cause a shift in the boundary between the transmission and absorption regions, which in these glasses is very sharp, toward the longer wave-lengths. The results of this investigation will be published shortly. At present Mr. Gibson is studying the effect of temperature change upon the absorption and fluorescence of the synthetic ruby. The sharpness of the bands and the well-marked dichroism of these crystals, both as

regards their absorption and fluorescence, make this investigation especially interesting.

Mr. H. E. Howe has completed the preliminary work in an investigation of the absorption in the ultra violet of solutions of a number of organic compounds of unusual purity. It is hoped that the method used will give more accurate quantitative results than have hitherto been obtained.

Professor R. C. Gibbs has been planning and testing apparatus for the study of the absorption spectra of pure organic compounds in various solvents. It is intended to extend the measurements throughout as wide a range of the spectrum as possible, including both the infra-red and ultra-violet regions. This investigation is being undertaken in collaboration with Professor W. R. Orndorff.

Nipher, Francis E., Washington University, St. Louis, Missouri. *Determination of magnetic effects of an explosion of dynamite.*

The work done in the summer of 1914 at Hessel, Michigan, established to my full satisfaction the magnetic disturbance due to "outbursts" of flame from burning powder (blasting powder) and from dynamite explosions. This is a local disturbance in the earth's magnetic field. The effect of the fog-horn of a steamer about half a mile distant was also observed on clear days, not on cloudy days. Verbal accounts of this work have been given to the Academy of Science of St. Louis. The secretary has written brief abstracts of my informal reports to Science. I also detected what appeared to be a magnetic field around a column of exploding dynamite. The direction of deflection was reversed when the direction of explosion was reversed. I do not regard this result as conclusively established. This would be a special case of Rowland's convection current.

PHYSIOLOGY.

Reichert, E. T., University of Pennsylvania, Philadelphia, Pennsylvania. *The differentiation of starches of parent-stock and hybrids.* (For previous reports see Year Books 9 to 13.)

The researches on the differentiation and specificity of corresponding vital substances have for more than a year past been restricted to the study of the starches of parent-stocks and hybrids, studying chiefly the peculiarities of the starch of each parent and tracing these peculiarities to the starch of the offspring. The actual laboratory work has been completed and only the final preparation of the memoir remains to be done, which preparation will be accomplished, it is hoped, some time during the coming winter. As previously reported, the methods pursued in a preliminary research (Publication No. 173, April 1912) on the differentiation of starches from different sources have been considerably extended and improved. Variables which under certain conditions may give rise to fallacious results have been to such an extent eliminated that the records obtained in this investigation are as closely in accord as those of carefully conducted determinations of melting-points, and hence practically accurate. The results recorded are in support of those of the preceding researches (Publications Nos. 116 and 173) in going to show that complex protoplasmic metabolites are specifically modified in relation to genera, species, varieties, etc., and hence that difference in corresponding substances constitute a specific means of plant and animal differentiation.

In the studies of starches the histological and polariscopical properties, iodine and aniline reactions, temperatures of gelatinization, and quantitative and qualitative gelatinization reactions with a variety of chemical reagents have been recorded. While these methods of investigation differ widely in character, the results are remarkably harmonious in the demonstration of certain principles of the greatest fundamental importance in normal and abnormal biology. Each property is shown to be an independent physico-chemical character-unit. Hence it follows that while a given property may by one of the means of differentiation appear more developed in the starch of one parent than in the other and be manifested in some degree of intermediateness in the hybrid, another property may appear in equal degree of development in the starches of the parents but be developed in the hybrid to same degree or beyond parental extremes in excess or deficit, etc. Each method and each reagent is an independent means of physico-chemical differentiation. Such relationships as are brought out by one may be very different from those elicited by another, so that we have as many independent character-units represented as there are methods and reagents. For instance, differences and identities in the processes of gelatinization of the starches of parents and hybrid, and of the hybrids of different crosses of the same parent stock that are not shown by one chemical reagent, may be rendered

apparent by another, and by one reagent differently from another. Thus, if the rapidity of gelatinization as determined by one reagent be exhibited in equal degree by the starches of the parents and hybrid, by another reagent it may be found that all three starches differ, and by another reagent all three will differ, but the order of differences may be reversed, and so on. In other words, the results recorded by the use of one reagent can not be taken as an index of what will be obtained by another. However, the property-values thus determined can be reduced to figures, and charts can be constructed which show that the sum total of these values is in case of each starch quite as distinctive of the genus, species, variety, or hybrid as are botanical characters.

Individualities of one or the other of the parental starches may or may not be observed in the starch of the offspring, and if present they may or may not appear in modified form. Moreover, the starch of the offspring may exhibit peculiarities that are not seen in either of the parental starches, and when two or more sets of hybrids have resulted from separate crosses of the same parental stock, each lot of hybrids may not only exhibit in common distinctive variations from parental characters but also independent individualities, and, as a corollary, differ from each other in well-defined respects. Hence, not only may a given hybrid be definitely attached to definite parentage, but also the hybrids of separate crosses may be recognized as such.

The studies of the starches of parent-stock and hybrids have been supplemented by corresponding and somewhat laborious histological examinations of plant tissues associated with some macroscopical inquiry. The results of this supplementary research are in striking accord with those of the starch investigations, and both are in entire harmony with universally recognized principles of the plant and animal breeder and with the dictum underlying these researches—"vital peculiarities may be resolved to a physico-chemical basis."

PSYCHOLOGY.

Franz, Shepherd Ivory, Government Hospital for the Insane, Washington, District of Columbia. *Investigation of the functions of the cerebrum.* (For previous reports see Year Books Nos. 4–10, 12.)

Work on the distribution of the motor areas for the limbs, as determined by physiological stimulation methods, was completed and part of the results has been published. The results show a great variation in distribution of the motor cerebral areas in different brains and an almost equally great variation in the areal distribution of the motor areas for the anterior and the posterior limbs in the two hemispheres of the same brain. These variations exist, it was found, not only for the totals of the areas dealt with, but also for the areas concerned with individual segments, or with types of movements. In combination with other facts from clinical and experimental investigations the results lead to an hypothesis of the mode of cerebral functioning which helps to reconcile many hitherto supposedly antagonistic phenomena.

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–13.)

During the past year further progress has been made in attacks on some of the central problems of genetics, viz: (1) What characteristics of mammals are inherited? (2) Do these conform with Mendel's law; if not, with what law? (3) Are Mendelian characters quantitatively variable; if so, is their variation controllable through selection or otherwise?

On the material side we have made good progress in the experimental breeding of guinea-pigs, rats, and rabbits, large numbers of which have been reared from pedigreed stock. In this work and in the study of the records obtained, I have had valuable assistance from Messrs. Sewall Wright and H. D. Fish. One of the important results of the year's work is the demonstration that multiple allelomorphs are of quite general occurrence among mammals. By this it is meant that a unit-character may assume several different alternative forms. For example, in guinea-pigs normal pigmentation and albinism are Mendelian alternatives (allelomorphs). This has long been known, but what has not been known is the fact that two intermediate stages of pigmentation are allelomorphs of these and of each other. These new conditions are *dilute pigmentation* and a *still lower grade of pigmentation* in which the fur contains only black or brown pigment, without yellow. The four conditions form a graded series of variations in one and the same Mendelian unit-character, in the production of which only a single genetic factor is involved, so far as we are able to discover. It follows that Mendelian factors are subject to quantitative variation, if our interpretation is correct. That the case is not an isolated one is shown by the occurrence of similar variations in other factors, both in guinea-pigs and in other mammals. Thus the agouti factor is subject to a series of allelomorphic variations in mice and rabbits as well as in guinea-pigs; and the extension factor and white-spotting factor also manifest multiple allelomorphic conditions. It would seem that this line of evidence must render untenable the presence-and-absence hypothesis in accordance with which Mendelian characters were supposed to be either present or absent, but not to vary otherwise.

Through a study of crosses between *Cavia cutleri* from Peru and domesticated guinea-pigs, further light has been obtained on the vexed question of size inheritance in mammals. Size inheritance has been correctly described as "blending," but a Mendelian interpretation suggests that this may be due to multiple independent factors, and invokes as evidence the greater variability of the F_2 generation as compared with the F_1 generation. Material of sufficient genetic constancy

to test this hypothesis is difficult to obtain. Our *cutleri* crosses are very good in this respect, since one race is fully twice as large as the other and the hybrids are fully fertile, while not extremely variable. The F_1 generation is about as large as the larger race, but F_2 is intermediate between the parent races. There is no significant difference in variability between F_1 and F_2. This result shows that the large size of F_1 is not due to Mendelian dominance, but to physiological vigor; it is not inherited at all, for it disappears in F_2.

We shall have to seek further for the law of size inheritance, unless we are content with the statement that size blends in heredity. Of course it is conceded that Mendelian factors often affect size, as in brachydactylism in man and in Dexter Kerry cattle, but that all factors or that even the principal factors affecting size are Mendelian seems extremely doubtful. Size in mammals seems to depend on general properties of the protoplasm rather than on special (localized) ones. Mendelian inheritance, on the other hand, involves localized determiners within the germ-cell, without which independent inheritance of characters is scarcely conceivable. In this connection it is interesting to note that we have discovered in rats two Mendelian characters which seem to have determiners located adjacent to each other in the germ-cell, so that "coupling" or "linkage" results. Such phenomena, well known for plants and insects, have not previously been recorded for a mammal.

The only extensive publication made since my last report is No. 205, by Dr. Detlefsen, which deals with the results obtained from *Cavia rufescens* crosses. Nine shorter papers dealing with particular phases of our experiments are included in the bibliography. (See Castle, Fish, Wright.) Particular attention is called to the paper by Castle and Hadley, which contains a brief report upon an investigation extending over several years carried out at the Rhode Island Agricultural Experiment Station in collaboration with Dr. Hadley.

My faithful assistants during the past three years, Messrs. Wright and Fish, are leaving on September 1 for positions of larger opportunity, the former to conduct investigations in genetics in the Bureau of Animal Industry, U. S. Department of Agriculture, the latter to be professor of zoology in Denison University. It is hoped that their valued service in these investigations may have fitted them for added usefulness in their new fields of labor. An extensive publication by Wright and myself on inheritance in guinea-pigs is in preparation.

Naples, Zoological Station, Naples, Italy. *Maintenance of two tables for American biologists.* (For previous reports see Year Books Nos. 2–13.)

The Director of the Station reports that on account of the European War no Americans have visited Naples to make use of the tables supported by the Institution.

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